

Nonnative American shad is another popular recreational fish. The runs of American shad are sometimes so large that when the fish migrate, sportfishers can be found on the banks of the Yuba and Feather rivers standing literally shoulder to shoulder. American shad are commonly taken with flies, jigs and small spinners and give a spectacular fight on light tackle. Although there is little available data on current shad population sizes, the sport catch has been low in recent years (DFG, 1991b).

Another popular anadromous sport fish is the native white sturgeon, which spawns in the Sacramento-San Joaquin River systems, and is fished in the Bay and Delta.

Major resident cold water fishes caught by recreational anglers in California include the rainbow trout, brown trout and brook trout, all of which are widely planted. The rainbow is native to California, and the brook and brown trout have been introduced, although because of planting most rainbow populations have varying degrees of genetic contamination. Trout are found primarily in smaller streams and in lakes, especially in the mountains, rather than rivers. Trout fishing is the most popular type of fishing in California (DFG, 1991d).

The Sacramento River has a popular resident rainbow trout fishery in addition to its anadromous steelhead fishery. However, because of elevated dioxin levels from paper mills, the Department of Health Services advises against eating resident trout from the Sacramento between Keswick Dam (just downstream of Shasta Dam) and Red Bluff.

Large warm water fisheries in state rivers exist in the Central Valley and on the Colorado River. The most numerous warm water game fishes are members of the sunfish family (*Centrarchidae*), including black bass, sunfish, perch and crappie, almost all of which are not native to California. Several catfishes, all introduced species, are also important for sport fishing. The record flathead catfish in California weighed in at 55 pounds, caught in the Colorado River (DFG, 1991c).

### *Recreational Boating*

California rivers provide all manner of boating experiences from white water rafting to yachting the twisted channels of the Sacramento and San Joaquin rivers in the Delta. Riparian vegetation and excellent fishing make some rivers a boater's paradise. For instance, in the Delta, thousands come to use the marinas, fueling docks, restaurants and bait shops which have sprung up around the edges of all the islands. There it is as easy to rent a boat as it once was to hail a steamer. The main commercial traffic now flows on purposely built deep water channels to Stockton and Sacramento, while the sloughs and cuts belong to the weekenders and vacationers.

Figure 21. River Canoeing.



Boating is another category of river use that begs for subdivision. From inner tubes to large cruising sailboats, anything that floats can be found on California's rivers, and usually is. One division that is often made is that between the white water users and the smooth water users.

Rafts, kayaks and canoes are taken long distances by individuals or commercial groups to run the rapids and canyons of California's white water rivers. These people are looking for the thrill of fast water, rushing rapids and waterfalls. A large commercial river-running industry has developed in California, supplementing the great numbers of people who own their own equipment and head for white water most every weekend. In 1989, the American White water Affiliation classified 2,256.3 miles of water, in 60 rivers and streams in California, as suitable for white water fun. Some of the more popular stretches are the South and Middle forks of the American, portions of the Cosumnes, Kings, Kern, Stanislaus, Klamath, Mokelumne, Trinity and South Yuba rivers, and the Truckee River from Alpine Meadows. Over 237 separate outfitters filed for commercial permits on the upper Klamath River, the lower Klamath River, the Salmon River and the South Fork American River in 1982 alone. This is a 2000 percent increase since 1970 (DWR, 1982).

The American River is the most popular of the rafting rivers in the state. Figures for white water rafters on the three forks of the American river, including both commercial and private trips, show a general increase even during the recent drought cycle. The approximate number of commercial raft trips on the South Fork of the American river have been kept for over 18 years (1975 -1992). The numbers average 59,882 raft trips per year. Even during the recent drought, the number of rafting trips on the American river increased.

Table 1. American River Commercial Raft Trips.

	South Fork	North Fork	Middle Fork	Total
1990	76,716	112	1,218	78,046
1991	63,308	184	1,253	64,745
1992	77,025	32	2,004	79,061

Under certain conditions other stretches of rivers become popular. The last period of drought (1987-1993) made portions of the Feather River, usually under Lake Oroville, a favored destination. Weekend water releases from Hetch Hetchy Reservoir create recreational rafting conditions on the Tuolumne (Sunset, 1991)

During this same three-year period, private rafters have gone down the South Fork of the Feather River in increasing numbers. During the most popular months of May through September the number of trips have been counted at 34,400 (1990), 33,746 (1991) and 37,100 (1992). This averages over 100,000 rafting trips each year. Rafting figures for the Tuolumne are counted as passengers. The numbers for 1986, including both commercial and private passengers, are 7,200. In 1991 that number had dropped to 5,100 commercial and non-commercial passengers.

It is reported by local commercial canoe operators that canoe trips on the Russian River have declined over the last three years (1990-92) primarily because of the effects of the drought, and in part because of other recreational activities in the area and pollution (the 1985 sewage spill apparently still concerns some boaters).

The smooth water enthusiasts generally have larger boats (though many canoers and kayakers like smoother water as well) or even houseboats. They often keep their boats in marinas, rather than using trailers to transport their boats from place to place. Most of these people use the Sacramento and San Joaquin rivers and the Delta for their trips. All types of boats, but especially houseboats, can be rented all over the Delta for leisurely cruising the quiet backwaters.

The Department of Motor Vehicles maintains registration records for boats as well as cars, including commercial boats. In September of 1992, their records showed Californians owning 811,740 boats, and that 97.8 percent of those were pleasure craft. Five years earlier, in 1987, the count was 696,513.

### *Recreational Swimming*

Swimming in California rivers is as varied as everything else about the state. There is the challenge of cold Sierra fed water, rough Kings Canyon flows, the warmer and more relaxing Russian River and the awesome Colorado River. To swim in rivers can be a challenge because of currents, submerged rocks and fallen trees. Another

challenge is river access. Although interest in swimming is high—a 1987 statewide telephone survey by the Department of Parks and Recreation gleaned that 59 percent of the state's population swam in rivers, lakes or ocean—there is no swimming access guide to California rivers.

Figure 22. Swimmers and Water Play.



Courtesy of U.S. Soil Conservation Service.

### *Nature Study*

The most direct way to learn is by experience. People learn about trees, birds and flowers by exploring them in their natural environment. No matter how much one reads about the "force of nature," better understanding of this force comes by observing the dramatic changes of a river bed after a major storm. The concept of nature's rejuvenating ability is understood when one observes the young willows sprouting by the newly created riverbank. People learn to associate nature with change and rebirth by walking along the river.

Thus riparian habitat zones attract more than plants and animals, they also attract those who want to study and appreciate this wildlife. And in California, it is the riparian habitats that are among the richest of the ecological treasures that people seek. The value of education as the key for fostering a stewardship ethic in Americans is recognized by the California Association of Resource Conservation Districts (CARCD). CARCD's resource staff promote a statewide program for an Adopt-a-Watershed curriculum beginning at the primary grades and extending through high school.

Surveys conducted by the U.S. Fish and Wildlife Service document that one of the most popular types of recreation in California is simply viewing wildlife. Surveys by the Department of Fish and Game report that the natural beauty of a location is as much, or



even more, of a draw to a specific spot for people fishing than is the number of fish caught. Tour buses, obviously not carrying hikers or fishers, regularly conduct millions of Californians and non-Californian tourists to Yosemite, through the Redwoods, along the coast and into the Mother Lode country. These people travel simply to take in the inherent beauty that is California's legacy. Even in major urban centers, such as Sacramento, the hundreds of thousands of users coming to the American River Parkway attest to the need people have to visit the splendor of rivers.

Figure 23. Bird Watchers.



### *The River as a Destination*

*Down through the middle of the Valley flows the crystal Merced, River of Mercy, peacefully quiet, reflecting lilies and trees and the onlooking rocks; things frail and fleeting and types of endurance meeting here and blending in countless forms, as if into this one mountain mansion Nature had gathered her choicest treasures, to draw her lovers into close and confiding communion with her. — John Muir, The Yosemite, 1874.*

*I had walked from Redding, sauntering leisurely, better to see the rocks and plants, birds and people, by the way, tracing the rushing Sacramento to its fountains around icy Shasta. — John Muir, 1874.*

The sight of a river cascading through granite and exploding into mist on the rocks is a sight that lures many hikers and campers out of California's cities and suburbs and into the hills. The state's rivers are destinations for picnickers, day hikers, backpackers and recreational vehicles every day of the year. Some come to fish or swim, or they bring their boats on trailers, but many come just to see and hear the river flow.

Table 2: State Park System Units on California Rivers, 1992-1993.

<b>Klamath/North Coast Region:</b>		<b>Miles of River</b>
Castle Crags State Park		3.1
Admiral William Standley State Recreation Area		.6
Grizzly Creek Redwoods State Park		3.4
Humboldt Redwoods State Park		56.5
Reynolds Wayside Campground		1.1
Richardson Grove State Park		2.4
Smithe Redwoods State Reserve		.8
Standish-Hickey State Recreation Area		5.4
Jedediah Smith Redwoods State Park		8.7
Hendy Woods State Park		3.3
Montgomery Woods State Reserve		.2
Paul Demmick Wayside Campground & Navarro River Project		17.3
<b>Modoc/Cascade Region:</b>		
Ahjumawi Lava Springs State Park		6.7
McArthur-Burney Falls Memorial State Park		5.0
<b>Sacramento Valley Region:</b>		
William B. Ide Adobe State Historic Park		.2
Colusa-Sacramento River State Recreation Area		.8
Bidwell Sacramento River State Park		1.7
Irvine Finch River Access (Unclassified)		.1
Woodson Bridge State Recreation Area		3.5
John Marsh Home (Unclassified)		.2
Calaveras Big Trees State Park		5.0
Brannan Island State Recreation Area		3.0
Delta Meadows River Park (Unclassified)		.6
Frank's Tract State Recreation Area		.1
Caswell Memorial State Park		4.6
Fremont Ford State Recreation Area		1.7
George J. Hatfield State Recreation Area		1.4
McConnell State Recreation Area		1.1
Great Valley Grassland State Park		1.5
Marshall Gold Discovery State Historic Park		1.1
South Yuba River (Unclassified)		23.5
Old Sacramento State Historic Park		.2
<b>East Side/Great Basin Region:</b>		
Lake Valley State Recreation Area		.5
Washoe Meadows State Park		.7
<b>Central Coast Region:</b>		
Pfeiffer Big Sur State Park		6.2
Carmel River State Beach		2.0
Castle Rock State Park		.5
Henry Cowell Redwood State Park		7.9
<b>South Coast Region:</b>		0
<b>Desert Region:</b>		
Picacho State Recreation Area		9.7

Scenic appreciation has been noted in various studies. Scenic beauty is regarded as a resource to be protected because it is intrinsic to recreational and cultural experiences on rivers. It may be that the public subconsciously evaluates quality of life or the state of our resources in an integrative way and scenery may be a prime indicator of that evaluation (NPS, 1990).

Camping along rivers is often a recreational activity of Californians. The State Park system (Table 2), includes 170 miles of rivers

and streams associated with parks, reserves, recreation areas and unclassified units. The 170 miles is approximately 22 percent of river units under California Department of Parks and Recreation administration. (Other units are on the ocean and lakes). Attendance figures for day use and camping facilities have been increasing steadily for all state-run units.

Another segment recreationists often overlooked includes the people who own larger boats and keep them at marinas on the river. Studies have shown that many such people never, or very infrequently, actually take the boats out on the river. They come down for the weekend to "get away" or to socialize without ever leaving their mooring (State Lands Commission, 1986).

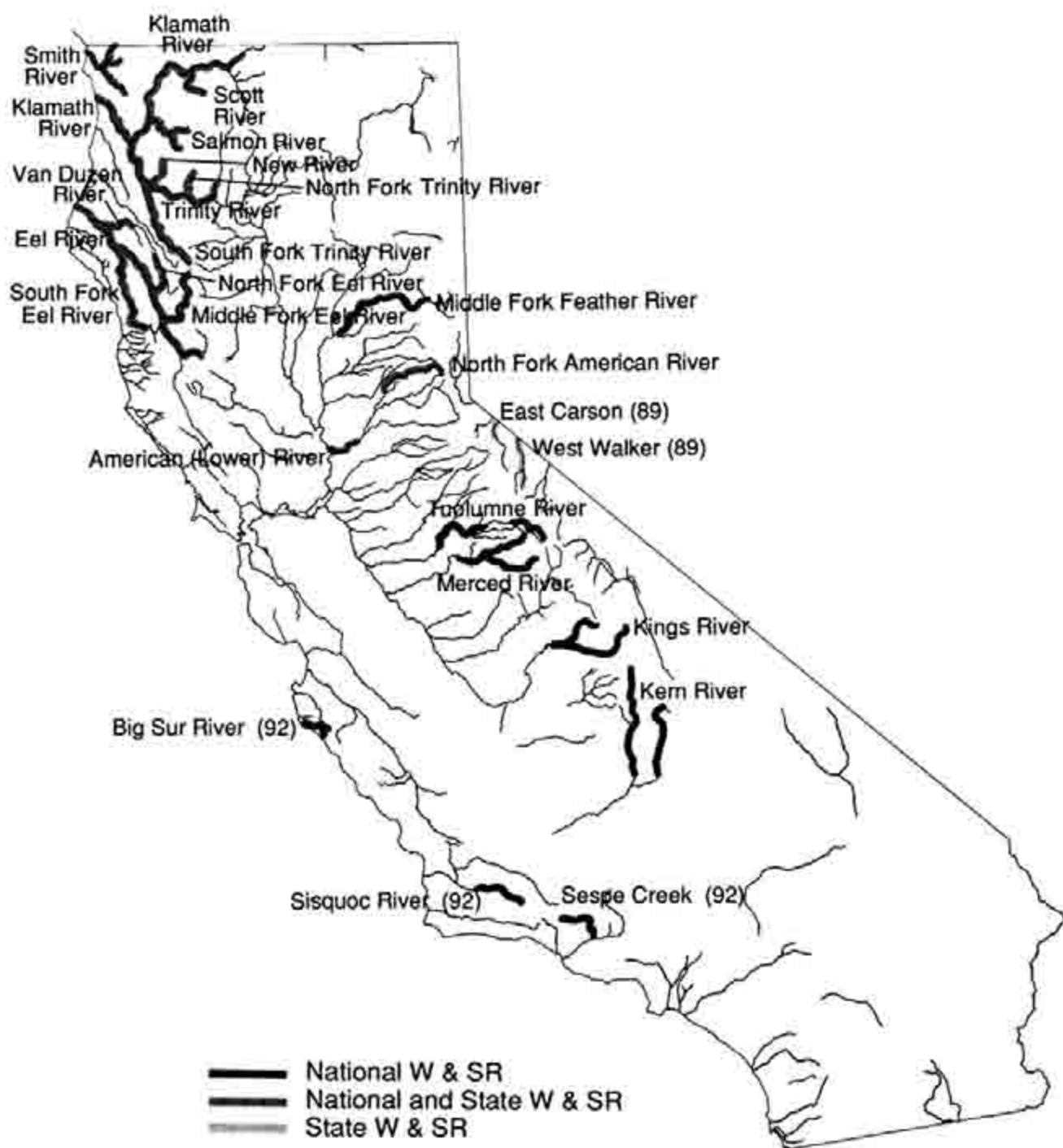
### *Wild and Scenic Rivers Act*

In 1968, the United States Congress established a policy of protecting some free flowing rivers and their outstanding values to balance the nation's existing policy of developing other rivers for their water, power and other consumptive resources. Rivers in the National Wild & Scenic Rivers System are designated "wild" (undeveloped and accessible only by trail), "scenic" (essentially wild but occasionally accessible by road) or "recreational" (accessible by road with some development allowed). All classifications prohibit new dams and major diversions, as well as guide the management of public lands within an average of one-quarter mile on each side of the river. The federal law does not prohibit development on private land along designated rivers, but allows for the acquisition of this land to protect wild and scenic values.

The passage of the 1968 federal act included the Middle Fork Feather River. In 1978, the North Fork American River was included in the system. Other state protected rivers (see Figure 24) were added to the federal system in 1981, garnering federal protection for the Smith, Klamath, Salmon, Scott, Trinity, Eel, Van Duzen and lower American rivers. In 1984, the Tuolumne was added to the federal system, followed by the Merced, Kings and Kern rivers in 1987. Sespe Creek, Sisquoc River, Big Sur River and the lower Merced were granted federal protection in 1992 (Figure 24).

In 1972, the California legislature passed a similar law to protect anadromous fisheries and exclude the North Coast's free flowing rivers from major water development. Except to observe local needs, this law prohibits the construction of dams and diversion structures, although this prohibition may not apply to federal projects. In addition, state protection is limited to the river bed up to the first line of riparian vegetation.

Figure 24. California Wild and Scenic Rivers.





The state Wild & Scenic Rivers System includes the entire Smith River and sections of the Klamath, Scott, Salmon, Trinity, Eel, Van Duzen and American rivers. In 1978, the North Fork American was added to the federal system, followed by the rest of the state rivers in 1981. The East Carson and West Walker rivers were added to the state system in 1989.

More than 1,900 miles of California rivers, or about 7 percent of all rivers in the state, are under wild and scenic protection. In addition, federal agencies have identified more than 200 river segments totaling more than 2,200 miles as eligible for federal wild and scenic designation. Of these, 35 segments totaling more than 550 miles have already been recommended for protection.

The Smith River is California's only major undammed water shed. Rising from its source in the Siskiyou Wilderness in the North Coast county of Del Norte, the Smith is considered the "Crown Jewel" of California's state and federal wild and scenic rivers. In recognition of this unique watershed, the 305,000-acre Smith River National Recreation Area (NRA) was established by Congress in 1990. Recognizing the nationally significant values of the North and Middle Forks of the American River near Sacramento, the federal Bureau of Land Management determined 48,000 acres encompassing the upper American river canyons to be suitable for NRA status in 1991, although Congress has not yet acted on this recommendation.

Figure 25. River Rafters.



Courtesy of Friends of the River.



# California Rivers: Effects and Consequences

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*Here in the U.S. we turn our rivers and streams into sewers and dumping grounds, we pollute the air, we destroy forest, and exterminate fishes, birds, and mammals—not to speak of vulgarizing charming landscapes with hideous advertisements. But at last it looks as if our people were awakening. Many leading men, Americans and Canadians are doing all they can for the Conservation movement.—Theodore Roosevelt, Our Vanishing Wildlife: Literary Essays (Works of T.R. nat. ed., Vol. 12, originally appeared in The Outlook, Jan. 25, 1913).*

There may be a relationship between the amount of landscape that rivers occupy and the importance with which people regard rivers. This may be especially true in the West where rivers do not always flow. This ephemeral quality belies their importance as environmental systems and resources for human use. As discussed in the previous chapter, rivers are major recreational attractions for Californians: sport fishing, swimming and boating are immensely popular.

Rivers are also used by humans for commercial purposes, including fishing, transportation, irrigation, sand and gravel mining, industrial and agricultural water supplies, and receiving waters for wastewater effluent. Apart from these important uses, rivers have intrinsic ecological and environmental values. Notwithstanding their importance in every aspect of human endeavor, rivers have been harmed in every way imaginable.

Agriculture and urban growth in California have demanded water for development and flood control. Water development generally has been through the impoundment of water behind dams or the diversion of rivers and tributaries to aqueducts conveying the water directly to farms and cities. Some dams also serve flood control needs, as do other measures, such as levees. Agricultural land use also results in the loss of riparian corridors and is a source of pollutants released to rivers. Urban land use is often traumatic to entire watersheds not only because of the construction of dams and flood control

projects, but also because of massive landform changes which alter runoff patterns and drainage networks. These and other insults interrupt springs, affect ground water tables, reduce riparian corridors and threaten the very existence of rivers.

Forestry and range management are major land uses in the 85 percent of the state which is not intensely developed. Like urbanization and agriculture, these activities have many significant effects on river systems, including watershed damage and pollution. In addition, mining in wildland watersheds and in river channels and flood plains has degraded myriad streams and rivers. Unfortunately both the legacy of past mining practices and current operations pose significant problems.

Before this century's human activities, the few potentially harmful substances that entered the water bodies came from Native American settlements along the shoreline, or from natural sources such as the weathering of rocks. Gold mining between 1853 and 1884 introduced the first major anthropogenic pollutant: an estimated 3,500 tons of highly toxic mercury used to extract gold. Mercury was followed by untreated industrial and sewage wastes from towns and cities. Implementation of the state Porter-Cologne Water Quality Act of 1969 and the federal Clean Water Act of 1972 led to rapid improvements in the quality of municipal and industrial effluent. Urban runoff contributes much larger quantities of many kinds of pollutants than do municipal and industrial sources. Pesticides are one of the most important components of agricultural runoff. It is estimated that agricultural drainage contributes more than 20 percent of the total time-averaged flow in the San Joaquin River, and most of its flow during the summer (DWR, 1986; Nichols et al., 1986).

Over the course of the 20th century, California's rivers have been put under great stress. This stress began almost immediately

Figure 26. Kern River Oil Fields.



Bryant Sturgess Collection.

with European/American use because of hydraulic mining for gold, navigation needs, the transport of logs, and water diversion for urban, industrial and agricultural development at a time of exceedingly rapid growth. Indeed, during the 20th century California saw the most rapid population increase of any developed area in the world, coupled with phenomenal rates of economic expansion and revolutionary agricultural practices.

This chapter identifies the principal human activities that have affected the ecological health of rivers' and streams' ecosystems in the 20th century. In this chapter we will discuss the factors of water pollution that affect the chemical, physical and biological characteristics essential for aquatic living resources and the status of these resources.

## Water Pollution

*Something will have gone out of us as a people if we ever let the remaining wilderness be destroyed. . . if we pollute the last clean air and dirty the last clean streams.—Wallace Stegner.*

The ecological health of an aquatic ecosystem is defined by its combined chemical, physical and biological characteristics—the concentrations of chemical constituents in its water, sediments and organisms; the condition of its physical habitat (e.g. streambed, banks, riparian vegetative cover and streamflow); and the health, variety and nature of the plants and animals that live around and within it (USEPA, 1988).

Water pollution is a broad term. It refers to the alteration of aquatic ecosystems so that aquatic life may be impaired or destroyed, or the fouling of water so that recreation and aesthetic enjoyment are diminished or no longer possible. These changes may occur from substances such as chemicals, sediments and excess nutrients

Figure 27. Sewage Treatment Plant.

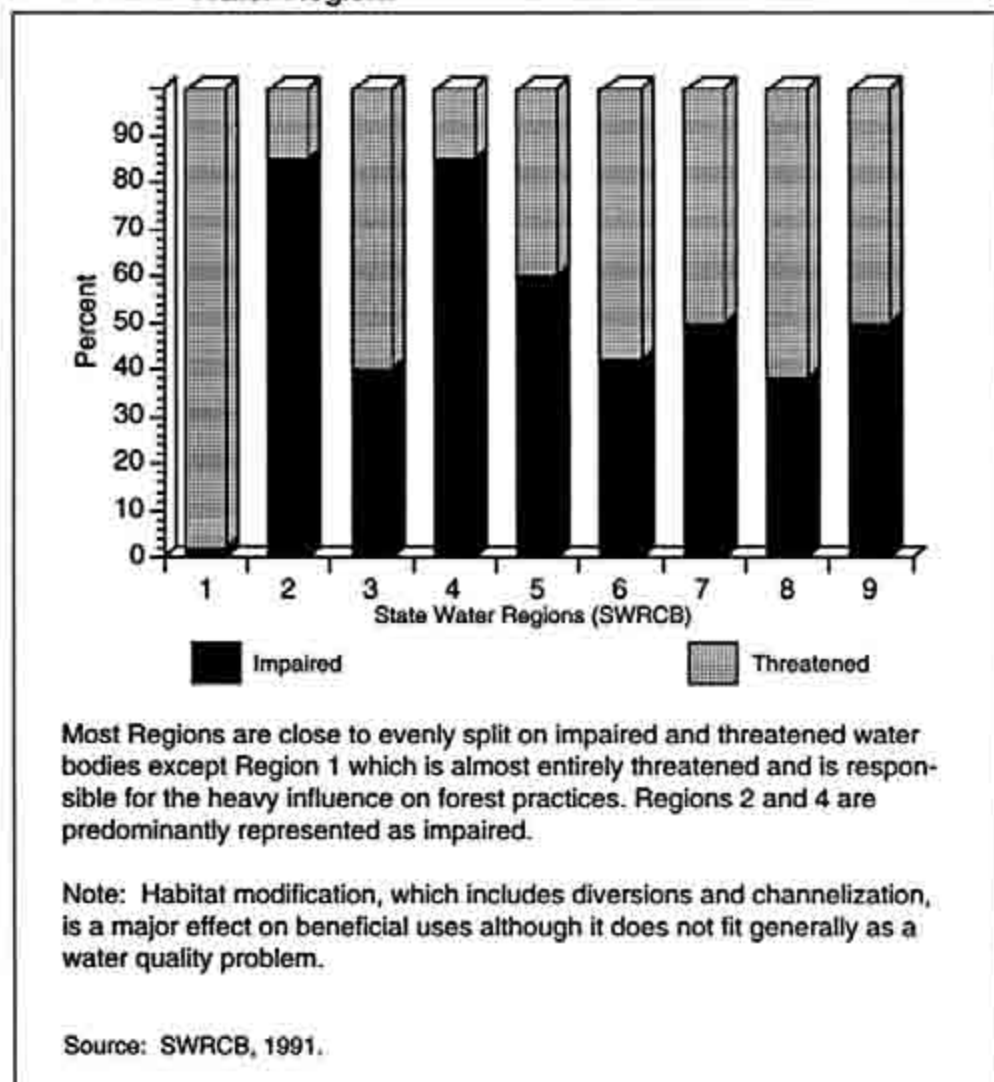




which are introduced into the water. However, water pollution also includes other actions that alter aquatic ecosystems, such as dredging or changing flows (SF Bay RWQCB, 1992).

All waters of California are required by federal law to be designated for "beneficial uses" that must then be protected. Such waters may be classified for support of aquatic life and contact recreation, and should be usable for fishing and swimming. The state is responsible for establishing criteria necessary to protect those uses. If these criteria are not met, the uses they are protecting may be "impaired" or "threatened" (SWRCB, 1991a). In general, impaired means the beneficial uses of water such as aquatic life or drinking water supply have been harmed and reduced. Threatened means the beneficial uses may be fully supported at this time but activities could impair these uses if not controlled (SWRCB, 1991a) (Figure 28).

Figure 28. Ratio of Impaired vs. Threatened Rivers by Water Region.



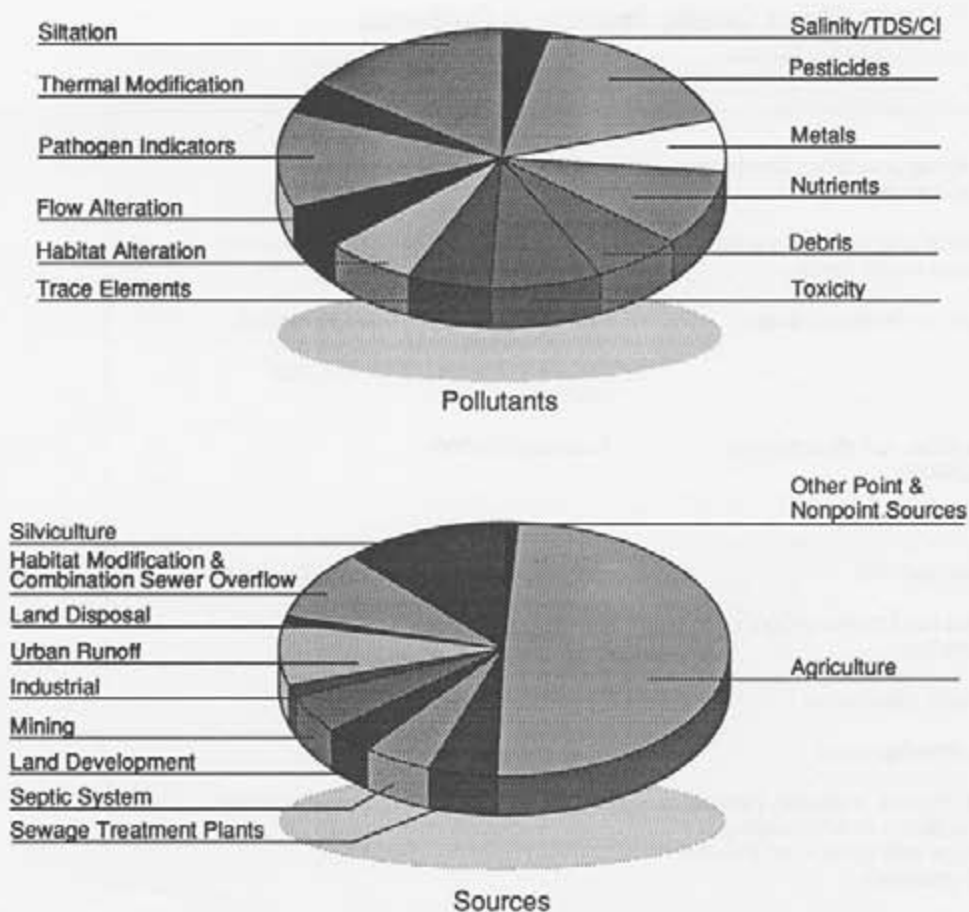
Most of California rivers meet state water quality standards and satisfy most goals set by the federal Clean Water Act (SWRCB, 1992a). The primary cause of water quality degradation in impaired water bodies in California is nonpoint source pollution. Nonpoint sources include agricultural, forestry and urban runoff (Charbonneau and Kondolf, 1991). Urban areas produce primarily point-source pollutants including storm drains in lower amounts than nonpoint agricultural sources, but they may cause locally severe effects, especially with high amounts of industrial discharge. Table 3 describes major water quality impacts in California (Adapted from Charbonneau and Kondolf, 1991).

Table 3. Major Water Quality Impacts in California.

Source	Impact
<b><i>Agricultural practices (Includes livestock and grazing)</i></b>	
Pesticide and fertilizer application, irrigation return flows	Toxics contamination, eutrophication, salinity
Animal confinement areas	Pathogenic bacterial contamination, eutrophication, ammonia toxicity, BOD/oxygen depletion, turbidity/siltation
Cultivation, soil disturbance, overgrazing	Turbidity/siltation
<b><i>Forestry Practices</i></b>	
Timber Harvest	Turbidity/siltation, BOD/oxygen depletion
Access road construction, site preparation	Turbidity/siltation
Pesticide application	Toxics contamination
<b><i>Urban Development</i></b>	
Urban Runoff, including pesticides and fertilizers in landscaping and drainage and spills from transportation corridors	Toxics contamination, eutrophication
Waste discharge (municipal & industrial outfalls, septic system leachate)	Toxics contamination, eutrophication, pathogenic microbial contamination, BOD/oxygen depletion
Air pollution	Toxics contamination, acidification
<b><i>Mining</i></b>	
Hard rock mineral mining	Toxics contaminants (e.g. heavy metals, acidification)
Instream and terrace aggregate mining	Turbidity/siltation

The most extensive source of water pollution impairing and threatening the state's rivers and streams is agriculture, primarily from excess nutrients, pesticides, herbicides, sediments and habitat modification (Figure 29) (SWRCB, 1991b). Other types of river pollution include elevated water temperature and toxic chemicals. Sources of these contaminants include municipal sewage and storm water runoff; resource extracts, such as mining; and silviculture (including timber harvest) (SWRCB, 1991a). Hydrologic habitat modification is caused by water diversions, flood control and urbanization.

Figure 29. Relative Percentage of Pollutants and Their Sources.



- The above pie diagrams depict the sum of Impaired and Threatened classifications of sources and pollutants for assessed rivers and streams of the state.
- The sources and pollutants shown above are heavily influenced by Region 5 with 41% of the State's assessed rivers.

Source: SWRCB, 1991.

## ***Pollutants***

Pollutants are substances or actions that adversely affect the physical, chemical or biological properties of the environment. The State Water Code (§13050[1]) defines "pollution" as "an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects either. . . 1) the waters for beneficial uses [or] 2) facilities which serve such beneficial uses." Additionally, the impairment of water quality by contamination is defined as pollution that creates a hazard to public health.

Pollutants are measured in terms of concentration (the quantity of a pollutant in a given amount of water), sediment or animal tissue. The units of measurement for describing pollutant concentrations are low because the occurrence of pollutants in the environment and biota are comparatively low. These units of measurement are commonly expressed as parts per thousand (ppt), parts per million (ppm), and parts per billion (ppb). Even parts per billion are significant to certain flora or fauna, causing death, deformity or mutations. Water's ability to ionize and dissolve substances and assimilate wastes is a major reason why aquatic ecosystems are on the one hand productive but on the other quite susceptible to pollution (Moyle and Leidy, 1992).

Discussed below are the principal types of pollution effects on aquatic biota and habitats: altered temperatures (usually elevated); depletion of dissolved oxygen; acute and chronic toxicity by inorganic chemicals, natural and synthetic organic chemicals, biological contaminants and suspended sediments; the smothering of bottom substrates by siltation; and habitat modification. Excessive pesticides, siltation, pathogens and nutrients chiefly from agricultural uses are the primary threat or impairment of rivers and streams (SWRCB, 1991b).

## ***Altered Temperatures***

Temperature pollution can occur with the discharge of industrial cooling water, agricultural drainage, the passage of river water through warm water ponds created by gravel mining pits, or surface reservoir releases. As an example, the Colusa Drain on the Sacramento River discharges irrigation runoff in flows up 2,000 cubic feet per second (cfs) at temperatures over 80°F, which is highly detrimental to salmonid smolts (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989). Decreases in flow also can result in increased water temperature. The removal of tree canopy by logging, grazing or other clearing near the channels of streams and small rivers also results in higher water temperatures.

Elevated temperature directly affects aquatic biota, especially those organisms adapted for cold water habitats. Organisms may be

killed outright or, more likely, subjected to chronic stress which predisposes them to premature mortality. Salmonid fishes are particularly vulnerable to high water temperatures (see discussion under fishes—Chapter 1). Temperature changes can also affect migration and spawning behavior (Dunne and Leopold, 1978).

### *Depletion of Oxygen*

Dissolved oxygen problems arise with the addition of biodegradable organic material, which is then worked upon by decomposing microbes. Sources of organic-matter pollution in rivers include agricultural runoff, wastes from food processing plants, human or animal waste discharges, and plant debris from crops or logging. Decomposition of organic matter requires a certain amount of oxygen, measured by an index called the Biological Oxygen Demand (BOD). If oxygen becomes completely depleted, anaerobic bacteria increase in activity, often producing noxious gases such as methane.

The addition of dissolved nutrients, for example from fertilizer run-off or sewage discharge, stimulates a bloom of algal growth. This over stimulation of the growth of aquatic plants and algae also cuts off light in deeper waters. This seriously affects the respiration of fish and aquatic invertebrates, leads to a decrease in animal and plant diversity, and affects the use of the water for fishing, swimming and boating. When algae dies it decomposes, adding enormously to the BOD. The phenomenon of artificial nutrient enrichment, rampant algal growth and subsequent oxygen depletion in a body of water is referred to as cultural eutrophication.

### *Toxicity*

Important river pollutants which are toxic to organisms include herbicides and other pesticides, heavy metals, chlorine, surfactants and ammonia. Changes in salinity and acidity also directly and indirectly affect river biota. Rainfall and irrigation can wash pesticides and herbicides used on agricultural lands into surface waters. These contaminants are generally very persistent in the environment and may accumulate in the tissues of fish and wildlife.

### *Inorganic Contaminants*

Sources of toxic substances include runoff and leachate from mines, e.g. the Penn Mine on the Mokelumne River and Iron Mountain Mine on Spring Creek, tributary to the Sacramento River; chemical wastes from pulp mills and refineries; chemicals used in agriculture or contained in agricultural waste; or drainage water (e.g. selenium and sulfate ions, Saiki et al., 1992). All take their toll on living resources and habitats. Toxic inorganic substances including metals



(such as mercury, lead, selenium and cadmium) can cause death or reproductive failure in fish, shellfish and wildlife.

### **Organic Contaminants**

Organic compounds include natural and synthetic chemicals. Many synthetic compounds are resistant to decomposition and are toxic to living organisms. Compounds containing chlorine or bromine, members of a group of elements known as halogens, are among the most persistent and toxic of organic chemicals. Familiar halogenated compounds include polychlorinated biphenyls (PCBs) and pesticides such as dichlorodiphenyltrichloroethane (DDT), and polynuclear aromatic hydrocarbons (PAHs) from combustion (vehicles), oil and petroleum products (benzene, xylene, toluene) whose detrimental effects may continue for decades once introduced into the environment.

### **Disease**

Biological pollutants, such as bacteria and viruses which cause cholera, hepatitis, salmonella and typhoid can enter water bodies from septic systems, untreated municipal sewage, recreational boat discharges, water contact in recreation (swimming) areas and in runoff from farms, feedlots and urban areas.

### **Habitat Modification**

Loss of habitat occurs when streams and rivers are modified by activities such as grazing, farming, channelization, construction of dams, dredging, gravel mining and interwatershed disturbance that leads to changes in channel morphology. Typical examples of habitat modification include loss of streamside vegetation, siltation, smothering of bottom dwelling organisms and increased water temperatures.

### **Sediments**

When it rains, silt and other suspended solids wash off plowed fields, construction and logging sites, urban areas and mined land. These suspended solids and sediments can have damaging physical effects. Increased turbidity decreases photosynthesis of aquatic plants, and can clog the respiratory surfaces and feeding mechanisms of aquatic animals. Sedimentation can smother benthic communities and alter habitat. Salmonids, which need clean gravel for successful spawning and early rearing, are particularly vulnerable to impacts from sedimentation.

Sediments constitute nearly half of the materials introduced into rivers from nonpoint sources (USEPA, 1988). Fine silt, part of the

overall sediment transported in rivers, remains suspended for long periods of time, producing extended areas of turbidity. Turbidity causes light to be scattered and absorbed, reducing light penetration and thus diminishing or even eliminating aquatic plant growth.

When plants die, their roots no longer act as anchors for soil in the bottom of the river bed, causing increasing turbidity. It has been demonstrated that the loss of aquatic plant life leads to the loss of associated snails and aquatic insects that depend on the plants and serve as a food source for young fish. Predatory fish depend on clear water for finding food. Thus, turbidity generally reduces the feeding of fish even if there is an abundance of food in the water. Many species of fish have complex reproductive and social behaviors that depend on visual signals which may be obscured in the turbid waters. Although living resources tolerate high levels of sediment in water for days or weeks, continued turbidity can result in a population finally succumbing to starvation, reproductive failure or cumulative stress.

### ***State Water Resources Control Board and Regional Water Quality Control Boards***

To gain an appreciation of the state of California rivers, one should understand the context of water quality assessment. The beneficial uses of rivers are varied and thus the health of the rivers consists of more than a drinking water quality standard. The process for assessing and monitoring river water quality is central to any restoration strategy. Because there is a need for this basic understanding of how river water quality is determined and the state of such determination in order to evaluate the status of rivers, the following discussion is provided.

The State Water Resources Control Board (SWRCB) has authority and responsibility under the Porter-Cologne Act for protection of the quality and beneficial uses of water. Nine Regional Water Quality Control Boards are individually responsible for developing Regional Water Quality Control Plans, (or Basin Plans) and ensuring compliance with the act. The status of California rivers' water quality is reported by the SWRCB in the *Water Quality Assessment* inventory (SWRCB, 1992b) that includes information about their characteristics and conditions. It is prepared by the regional boards and varies widely in what is measured and in consistency (John Norton, SWRCB, pers. comm. 1/1993). The prioritization step of the state's Clean Water Strategy (SWRCB, 1991a) involves the preparation of water body fact sheets, determination of resource value and water body condition. Resource value and condition ratings are prepared for higher priority waters, as determined by the regional boards, and for those waters that are water-quality limited (SWRCB, 1992b).

The SWRCB assesses river water quality to determine if the river can strongly support its uses, such as aquatic life and wildlife

and recreation. Those rivers which do not fully support these and other purposes are judged to be impaired. The regional boards' assessments have determined optimal strategies for achieving water quality and distribution of assimilative capacity for each major river basin. Assimilative capacity is a measure of a water body's ability to meet standards or provide "beneficial uses" under increasing "loads" of individual pollutants. The Total Maximum Daily Load (TMDL) for a few pollutants and some hydrologic units has been determined—for instance, San Francisco Bay, Morro Bay, Central Valley and North Coast/Klamath regions and Santa Ana and Truckee rivers. However, the SWRCB has recently initiated an alternative "watershed" approach, rather than determining assimilative capacity for each major pollutant. These "watersheds"—not water basins—are defined in area by pollutants, beneficial uses and land use change regimes (John Norton, SWRCB, pers. comm., 1/1993). This area definition allows water quality standards to be achieved in a system rather than at isolated treatment facilities. For instance, if a wastewater treatment facility charged by law to meet a water discharge standard can identify upstream sources of the pollution which are outside its jurisdiction, then a multi-jurisdictional collaborative effort could achieve the required water quality standard. For impaired streams, the SWRCB and the Regional Water Quality Control Boards adopt water quality standards to mandate enforcement authority or to encourage practices to improve the water quality.

Testing the effects of pesticides and herbicides on aquatic life is an ongoing effort. The Regional Water Quality Control Boards must identify which components in the stream or river's chemical makeup are toxic. Toxicity is determined by stream water survival and the reproduction of certain test animals. Toxic levels may be too low to kill, but they can inhibit reproduction and eliminate the food supply. Once the toxic level is determined to be caused by a pollutant, the source of that pollutant must be identified.

Annual reports on the state's river water quality only document the impairment and suggest its source; they do not provide remedies or implementations. For example, the state does not have requirements for integrated pest management (IPM) to reduce the application of pesticides or herbicides; nor does the state have a comprehensive Best Management Practices program to require vegetation buffers between crop fields and streambanks. Such buffers would delay or block the chemicals from entering surface waters or "treat" them through plant uptake and, in many instances, substantially reduce their toxicity. These buffers would also trap sediment which is the principle carrier of pollutants.

Currently the state does not have a complete description of each river basin that would be adequate for an environmental assessment. There is no comprehensive list of environmental problems in the river basins. These existing partially descriptive basin

plans are being updated. Fact sheets on 250 water bodies, including rivers, briefly describe the beneficial uses, pollutants and causes of impairment. However, there is no single document with these descriptions. Reports and assessments that do exist are based on different protocol for water quality evaluation. Although there are standard laboratory procedures set by USEPA, and state regulations for environmental indicator testing, it is difficult to compare data from different regions and different water conditions due to regions' subjective determinations based on "Best Professional Judgement." Thus, there is no consistent method by which watersheds are characterized nor are there consistent criteria to measure the ecological condition of aquatic, wetland or riparian systems to evaluate either the need for remedial action or the effectiveness of management actions on beneficial uses.

The first large scale attempt to create a coordinated voluntary watershed resource management plan based upon needs of landowners and citizens is the Napa River Resource Management Plan of 1992. A \$61,000 grant was awarded by the State Water Resources Control Board to the Napa County Resource Conservation District to help develop the plan. Recommendations to landowners and public agencies about ways to enhance and protect the natural resources of the watershed will be made. The stated objectives are to: encourage development of practices that will increase biological diversity; increase the long-term health of agriculture and open space lands; enhance and protect fisheries; public education programs to avoid urban pollution; integration and enhancement of wildlife habitat throughout the watershed.

The program will consider the entire watershed from Mt. St. Helena through the Napa Marsh State Wildlife Area. Several local and state agencies are providing technical assistance. The program could be a model for other water region areas seeking long-term methods of protecting and enhancing natural resources under pressure from increasing population and development. The plan is intended to demonstrate the integration of resource conservation principles in land management planning as a method of water quality protection (Napa RCD, 1992).

## **Effects of Mining**

### ***Instream and Terrace Aggregate Mining***

Sand and gravel are used for a large variety of construction activities including roads and highways (base material and asphalt), pipelines (bedding), septic systems (drain rock in leach fields), and concrete (aggregate mix) for highways and buildings. Since the end of World War II rapid population growth and the consequent construction boom in California, the demand for aggregate has been strong. In



1986, the production of sand and gravel in California, primarily derived from river channels and their flood plains, was estimated at 128.5 million tons with an estimated value of nearly \$500 million (Sandecki, 1989), nearly double the estimated production of 65 million tons in 1955. Aggregate mining is the largest mining industry in California.

Aggregate is derived principally from pits in active flood plains, pits in inactive river terrace deposits or directly from the active channel. Other sources include hard rock quarries and mining from deposits within reservoirs. Although no figures are available to specify the proportion of total production derived from various sources, it is clear that the great majority of aggregate is derived from active channels and adjacent alluvial deposits.

Figure 30. Russian River Aggregate Mining.



Figure 31 shows where aggregate mining in and adjacent to California's rivers is occurring. This information was derived from databases maintained by the State Lands Commission and the Department of Conservation, Office of Mine Reporting and Reclamation Compliance. The Department of Fish and Game is also responsible for issuing "streambed alteration agreements" which are prepared at the regional level; thereby making collection of complete information difficult. Local governments may also issue permits for some mining activities. The completeness of the information on instream aggregate mining is therefore problematic due the variety of federal, state and local agencies with regulatory authority.

Extraction sites present a problem for regulators for a variety of reasons. Those reasons include water quality, public access and navigation, loss of riparian vegetation and anadromous fisheries habitat, downstream replenishment, site reclamation responsibilities, structure damage (bridge and highway crossings) and the extent of aggregate supplies.



Figure 31. Map of Instream Aggregate Mining Sites.



There are currently two major efforts, including both public and private organizations, aimed at coordinating efforts and sharing information on the extent of gravel extraction in the state. First, the Instream Gravel Committee was established at the state level in 1993 to provide a coordinated effort to manage gravel extraction activities by identifying impacts and providing a streamlined process for review of these activities. Thirteen state agencies and the U.S. Army Corps of Engineers participate. The second effort is the Mad River Memorandum of Agreement (MOA). It was developed to address gravel extraction activities on the Mad River in Humboldt County. The MOA is one of the few concerted effort among industry and local, state and federal agencies and public interest groups to identify and address potential impacts of gravel extraction for a specific region while providing for an agreed level of extraction. The State Lands Commission participates in both of these efforts.

Aggregate derived from active riverbeds is especially desirable because it typically requires little processing or transportation. Natural river processes eliminate weak materials by abrasion and attrition, so the resulting deposits are durable, rounded, well-sorted, and relatively free of interstitial fine sediment. Suitable deposits are often located near the markets for the product, which reduces transportation costs. This is especially important to this industry, where a general guideline is that the cost of the product doubles with each 25 miles of transport (Randy Sater, Teichert Construction Company, Sacramento, pers. comm., 1991).

Until recently (and still in many areas) the environmental costs of instream gravel extraction have not been factored into production costs, making instream sources more attractive than alternatives such as dry terrace mines (in which interstitial fine sediment content is often greater, requiring additional processing), quarries (from which rock must be crushed, washed, and sorted), or distant sources, such as reservoir deltas, involving greater transportation costs.

As described in Chapter 4, the sediment in the bed of a river is a dynamic feature, in transit through the system during floods. The flux of bed sediment depends on the supply of coarse sediment from the watershed and the transporting power of the river. In addition, transport rates vary over space and time. If the sediment flux is altered, the river channel is likely to adjust to the changed conditions. Instream gravel mining, by removing this sediment continuum, disrupts the preexisting balance between sediment supply and transporting power.

The concept of replenishment rate is commonly applied to instream gravel mining to specify acceptable levels of sustained yield. The notion is that if the harvest rate does not exceed the rate at which coarse sediment is delivered from upstream, the harvesting can be sustained without impact on the channel system. However, when viewed in the larger context, this extraction site can be seen as

the "upstream" from which downstream reaches derive their coarse sediment supply. If the sediment in transit through the system is rerouted out of the channel into gravel trucks, the flow of gravel is interrupted and downstream reaches are deprived of their sediment load. One effect of this is essentially the creation of "hungry water" downstream of extraction sites. When this happens, the river will typically expend its excess stream power by eroding bed and banks. Thus, channel incision and instability may result downstream of extraction sites even if the extraction rate does not exceed the "replenishment rate."

The most dramatic effects of instream mining occur when pit mining is conducted within the active channel. By excavating large pits, whether shallow or deep, the equilibrium profile of the stream bed is altered and the channel must adjust to the locally steeper gradient upon entering the pit. This steeper gradient creates a stream power excess which is generally capable of eroding the bed, causing incision, often both upstream and downstream of the pits. As the streambed degrades, the material remaining on the surface will coarsen as the finer material is transported away. This leaves a coarse lag and an armor layer similar to that seen downstream of dams. In severe cases, the degradation will continue until bedrock or older substrates under the recent alluvium are uncovered.

Incision has many direct effects, notably the undermining of bridge piers and other structures, such as has occurred under the Highway 299 Bridge over the Mad River and bridges over the Russian River (Figure 32). The cost of such damage to bridges through 1984 in California probably exceeded \$12 million (Kondolf and Matthews, 1993). Degradation can induce channel instability and

Figure 32. Exposed Pilings of Bridge on Russian River (Healdsburg).



trigger bank erosion and channel migration in formerly stable reaches. The physical alteration of the stream channel may result in the destruction of existing riparian vegetation and the reduction of available area for seedling establishment. Loss of vegetation impacts riparian and aquatic habitat by causing a loss of the temperature-moderating effects of shade and cover, and habitat diversity. As noted above, bed coarsening results in loss of spawning gravels for salmonids. Extensive degradation may induce a decline in the alluvial water table, as the banks are effectively drained to a lowered level, affecting riparian vegetation and water supply wells (Woodward-Clyde Consultants, 1976).

By altering the natural channel configuration, even low-volume gravel bar skimming operations can reduce habitat diversity by producing a wide, shallow channel lacking in the pools and cover needed by fish, and potentially increased water temperatures. In addition, the cumulative effects of skimming approach those of instream pit mining, i.e. bed degradation.

Because of environmental impacts related to mining in the active channel, more and more aggregate is being mined from river terraces. Terraces are made up of flood plain deposits, but are somewhat isolated from the current river due, for example, to bed degradation or flood control. In terrace mining, huge pits are excavated alongside the channel, leaving a small strip of unmined bank to act as a levee between the active river channel and the pits. Because the pits are dug much deeper than the groundwater elevation (and deeper than the original river bed) the pits become giant ponds after mining.

Terrace pit mining can cause many adverse environmental effects. If the river should meander and "capture" the terrace pits, the flowing river habitats would be subsumed into a system of warm-water lake habitats. For example, flood waters breached a levee on the lower Merced River in 1986 and changed the course of the river to flow into a terrace mining pit. The low Merced salmon population was further stressed by these new migration impediments and increased exposure of the juveniles to predation. DFG's 1993 proposal to rebuild the levee and restore the river to its channel is under review. In addition, terrace mining replaces land, which may be useful for agriculture or riparian habitat, with ponds. Terrace pit lakes can provide wetland habitats, but the side slopes are usually left so steep after mining that extensive reclamation is necessary to gain any environmental benefits.

### ***Suction-dredge Gold Mining***

California rivers and streams are still mined for gold, by both recreationists and commercial enterprises. All the larger operations, both commercial and recreational, use similar methods. A suction dredge is floated in the stream and a four to ten inch hose is guided



over the bottom, sucking up water, sediment, small rocks and, it is hoped, gold nuggets. This flow is passed over riffle boards or "rockers" to separate the gold. The separator may be on shore, or floating attached to the dredge. In either case, the fully mixed flow is returned to the stream. In smaller streams, this flow may be a significant percentage of the total stream flow. There are no changes to the temperature or additions of chemicals in these operations. Other than the increased turbidity, the major damage to the stream is to the bottom environment, which is effectively "vacuumed" clean. Most aquatic organisms, sediment and gravel are removed from the site of the dredge operation and deposited downstream in a pattern determined by flow and channel characteristics. In coastal rivers, dredger holes excavated in the bottom can prove hazardous to wading anglers fishing for steelhead or salmon. Considerable damage does occur by illegal activities such as excavation into stream banks, which can wash out large amounts of soil.

Impacts of dredging are influenced by the dredge size and density, stream size, the fineness of the sediments and flow regime. For example, observations on the North Fork of the Feather River and the North Fork of the Yuba River indicated that the dredging activities effects were limited to the site. This is contrasted with observations at a tributary of Butte Creek which was completely channelized and riffles were transformed into exposed gravel bars by the operation of one dredge (Harvey, 1986). In general, fish and invertebrates apparently were not highly sensitive to dredging. The fluctuations in flow, turbidity and sediment source can greatly reduce the long-term impact of dredging. Studies indicate that suction dredging effects can be short-lived on streams under the right conditions and appropriate operations (Harvey, 1986).

Figure 33. Minerals Leaching from Abandoned Mine.





## ***Mining Pollution***

Thousands of inactive California mines pocket the state. (Figure 33). Many have gaping holes and fractures spilling toxic substances into streams and rivers. Past hydraulic and explosive mining exposed rock to weathering conditions. Now, air and water act on these exposed interiors to corrode and leach pollutants from the mine ores.

Mine discharge into surface waters is a near-statewide problem (Rick Humphries, SWRCB, pers. comm., 4/1993). Ninety-four mines have been studied for their threats to water quality. The magnitude of toxic discharge from the other thousands of mines is unknown. This state of affairs is partly due to the fact that current law holds anyone attempting cleanup liable for their actions in the remediation effort; thus the cleanup of abandoned mines usually is dependent on public financing.

Acid drainage causes more damage than any other known mine pollutant (Paul Helliker, Cal EPA pers. comm., 1993). When pyrite ore is exposed to the environment, the actions of water, oxygen and bacteria change pyrite to an acid solution as corrosive as battery acid, capable of dissolving metals.

Mining wastes which threaten aquatic life also include cadmium, mercury and asbestos. Ninety percent of the copper, zinc and cadmium measured in the Sacramento River originate from inactive mines (Paul Helliker, Cal EPA, pers. comm. 1993). Other wastes are chromium, lead and nickel. These metals accumulate in fish with traumatic effects to the fishes' reproduction and, in some cases, lives.

### **Acid and Heavy Metals**

Mine remediation is sensitive to liability issues. For instance, a bill was proposed in 1992 by the SWRCB staff to plug abandoned or inactive mines leaking acid wastes into the state's water. It also contained authority to develop, demonstrate and evaluate treatment and reclamation techniques for abandoned mines. The proposed bill was not approved by the SWRCB for submission to the legislative process due to concern about possible state liability if projects failed to achieve success.

Iron Mountain Mine near Keswick and Shasta dams discharges more metals to rivers and streams than any other source in the nation. Approximately one ton of copper and zinc are released daily. This is equal to one-fourth of the discharge from all industrial and municipal sewage treatment plants in the country. It is also the largest source of copper, cadmium and zinc in the Sacramento River watershed (USEPA, 1993).

Mine pollution cleanup strategies include treatment plants to extract copper and neutralize acidity with limestone, revegetation

and creating artificial wetlands. Plants are used to absorb water and prevent moisture from seeping into mines; downstream wetlands "treat" the toxic drainwater.

### Effects of River Navigation

When California's road system was paved, and motor vehicles became affordable and reliable, the era of the river boat was over. Commercial traffic shifted, for the most part, to the roads, and the steamboats were left to fall apart on the mud flats up and down the rivers. Major shipping still came to the river mouth towns that had become seaports, and to the inland sea that was the San Francisco-San Pablo Bay system, but the only true river ports were Sacramento and Stockton.

Both Sacramento and Stockton now have artificial channels leading to their port facilities. Stockton's is the oldest (1950), and consists mostly of cuts that straightened out the main channel of the San Joaquin river. When Sacramento's turn came, a completely artificial river, the Sacramento Deep Water Channel, was carved out of the valley soil (1963). The cargo which passes through these ports is largely related to agriculture and forest products (Figures 34 and 35).

Figure 34. Port of Sacramento Total Cargo Tonnage, 1989.

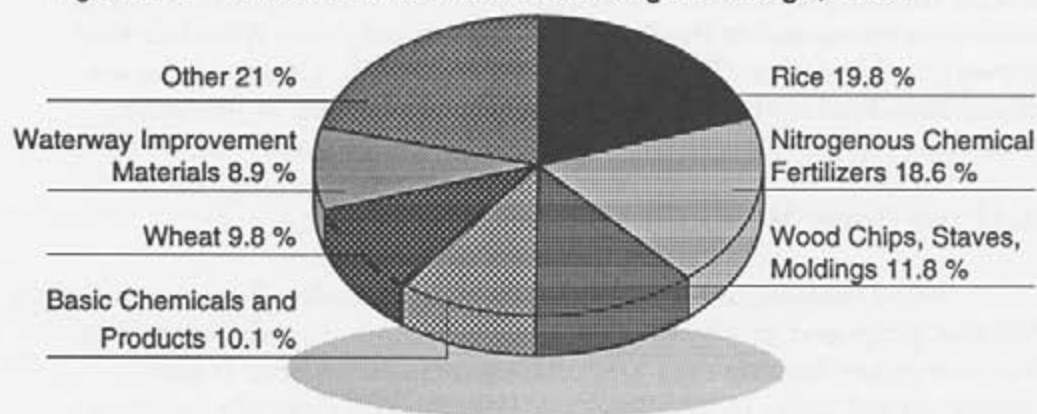
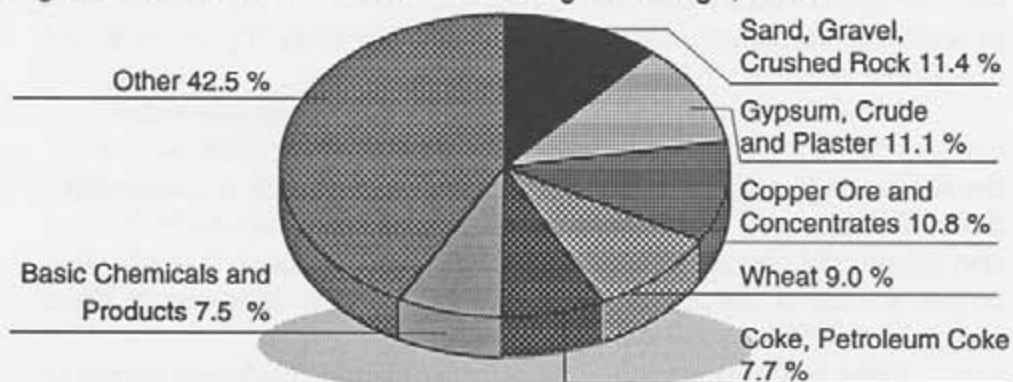


Figure 35. Port of Stockton Total Cargo Tonnage, 1989.



Source for Figures 57 and 58: U.S. Army COE, Waterborne Commerce of U.S.

It was the river traffic that first brought engineers to California. As the boats got larger, and the water shallower (see Chapter 1), the engineers were called upon to "keep the rivers open" for commercial navigation. This meant both clearing debris from the river and "improving" the channels, and as dredge technology improved, they straightened them. Commercial navigation included barges, deep draft ships and other boats.

### *Dredging and Clearing*

As noted, one kind of channelization is the creation and maintenance of clear waterways for navigation. Former commercial river boat traffic was much more important than it is presently, but shipping still exists on the Sacramento and San Joaquin rivers. Recreational boating, including commercial fishing guide services and touring, are increasingly important activities on many California rivers.

Prior to the great floods of 1865 and 1878 there was little need to do any real "navigation improvements" on the channels used by the steamship companies. The upper San Joaquin, the Mokelumne and some of the smaller rivers outside the Delta needed work, but it was more brush clearing than channel cutting (MacMullen, 1944). The boat owners did most of the work on their own, often as part of the job of getting wood to keep the boats going.

As discussed elsewhere in this report, hydraulic mining changed the depth of rivers and sloughs so that navigation either ceased or depended on dredging. Many of the channels in the present Delta have been deepened, created or widened. Some modifications were done for navigation, and some were done for drainage and reclamation.

Ambitious dreams of connecting Stockton and Sacramento directly to the sea for modern deep draft vessels have been around since the turn of the century. The Venice and Mandeville Cuts on the San Joaquin were the beginnings of the Stockton Deep Water Channel. Its final path was a straightened and deepened San Joaquin River (Bauer et al., 1983).

The Port of Stockton was formally established in 1933. Currently the port can accommodate ten ocean going vessels at one time. The Port of Sacramento began construction on the bypass of the Sacramento River through its Deep Water Channel in 1949. The artificial channel was cut from Cache Slough up to the City of Sacramento, connecting with the Sacramento River by a barge lock. Five ocean going ships may be accommodated at once. The port is in the process of deepening its channel by five feet to accommodate ships with up to 36 feet of draft.

Keeping navigational channels open and clear has been the U.S. Army Corps of Engineers' (Corps) chief responsibility since it was established in the Department of Defense. In California, with the exception of dredging in the major harbors, this has meant work on the San Joaquin and Sacramento rivers. By 1917 the Corps had removed 24

million cubic yards of dredged material from the Sacramento, up to the junction with Cache Creek. By the end of the 1930s, the Stockton channel was dredged to a 30-foot depth, over a width of 100 feet.

Completing the two deep water channels to Stockton and Sacramento, the Corps ceased its general navigation dredging of the other channels of the Sacramento River, the Delta and the San Joaquin River. Now, the only dredging outside of the two main channels is an occasional removal of "hazards" to navigational boating. Other rivers maintained by the Corps are Petaluma and Napa.

Local efforts by public officials, commercial ship crews, and recreational boaters supplemented Corps activities by clearing fallen logs for safe and easy navigation (Sedell et al., 1988). The State Lands Commission sponsored a snag removal project in the Delta and on the Sacramento River to remove hazards to navigation during the low flows of the 1977-1978 drought.

Navigation improvements on some of California's smaller rivers are carried out by the Corps as a "mitigation" for lost recreational use as the result of the Corps dams. This work involves the removal of boulders, tree stumps and some gravel bars on the downstream side of dams. For example, a variety of capital-intensive, recreational improvements to the reservoir behind New Melones Dam as well as to the lower Stanislaus River below the dam were promised to mitigate the destruction of the Stanislaus River's white water resources. Those improvements, for the most part, never were provided.

Maintenance dredging affects water quality by increasing turbidity and possibly releasing toxic substances from bottom sediments. The deepening of shipping channels requires more frequent dredging: The deeper a channel is dredged, the slower the water moves within it, allowing more sediment deposition. Another concern with water quality on the lower San Joaquin and Sacramento rivers is that the deepened and widened channels may allow increased salt water intrusion into the Delta (San Francisco Estuary Project, 1992a). Dredging and dredged materials disposal may cause direct impacts to marshland, aquatic and riparian habitats. There is an emerging interest in reusing the dredged material for tidal wetlands restoration and replenishing organic material in subsided tidal lands and Delta tract lands (if the dredged material is without toxic levels of pollutants, such as heavy metals). Also considered for the reuse of dredged materials are Delta levee stabilization or repair. The salinity of the dredged material from the Bay may limit its use.

The removal of snags and other large debris from waterways eliminates underwater structures that are biologically significant. These "structures" and other channel irregularities create back eddies which collect organic debris, provide cover, and are surfaces for algae and invertebrates to colonize. The increasing awareness of the value of snags and submerged elements creates a



conflict of priorities between those responsible for river navigation—both commercial and recreational—and those protecting the rivers' ecology.

## Effects of Timber Harvest and Grazing

### *Timber Production*

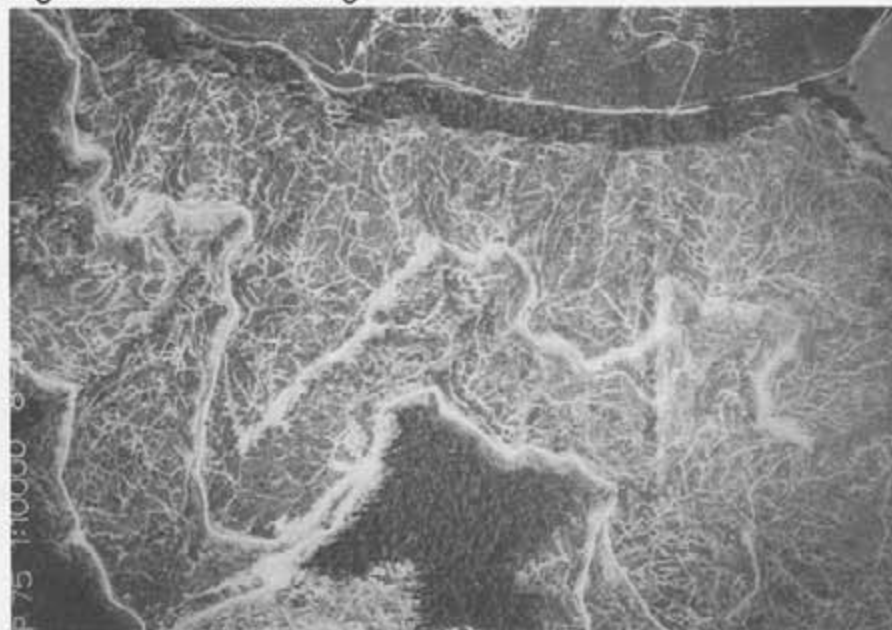
Ninety percent of the state's annual runoff originates from forest and rangelands (DFFAP, 1988). Therefore, forest and range management activities can have significant influences on our river systems. Forest management for the production of wood products is the primary land use in the North Coast and Sierran regions of the state.

### **Timber Operations**

The management of land for timber production involves many activities which can affect watersheds and river systems, including the construction of access roads and logging operation areas, tree removal, the preparation of the site for reforestation, and the control of competing vegetation, disease, insect and animal pests.

After deciding upon the harvest strategy, the first step necessary in timber production is the layout and construction of access roads for the transport of logging equipment into and logs out of a harvest area. Paved highways and county roads are used as far as they go, but often additional dirt roads are needed to extend truck access into an area. Along with a road network, skid trails and with cleared areas for equipment and log storage, called "landings" or "yards," must also be built in strategic locations throughout a logging site.

Figure 36. Clear-cutting.





Logging may be carried out under three general categories of forest management: 1) clear-cutting—systems which cause wholesale conversion of a forest stand, by cutting down all or nearly all of the trees (Figure 36), 2) selection cutting—systems which harvest only a portion of an area's timber at a time, or 3) thinning—removing the smaller trees in the stands to promote growth of desired trees. In either 1) or 2), it is the largest trees, suitable for lumber production, which comprise the primary harvest.

After the trees are felled, the trunks are cleared of limbs and cut apart into logs to be removed from the area. Gathering and moving logs, or yarding them, requires heavy equipment and experienced workers as the logs are dragged, pushed, pulled and hoisted uphill or down to log landings. In California, most log moving on slopes less than 30 percent is done by large tractors driven over the harvest site, causing considerable soil disturbance. Removing logs from steeper slopes by a cable system or even by helicopters causes less damage to the land; however, both are more expensive than tractors and so are less frequently employed when tractor logging is feasible.

Site preparation following logging involves disposing of the branch and leaf debris left behind (the slash), usually by burning it. After this, tree regeneration by natural or artificial seeding or planting occurs.

As young trees of the desired commercial species begin to grow, so often do noncommercial trees and shrubs which may compete with the harvest crop for water, light or growing room. If this happens, herbicide spraying may be carried out on the cut-over lands. Any spraying on any timber lands is usually met with public outcry.

### **Past and Current Efforts**

Although California is characteristically Mediterranean in climate, with a wet season and a dry season, the North Coast receives an exceptional amount of rain. Here, where most of California's timber production occurs, there are steep and unstable slopes. This and the amount of rain cause high rates of erosion and mass wasting (landslides) generating significant quantities of sediment. Through these processes river beds and riparian habitat may be buried or scoured, and flood and landslide debris may be deposited by lower flood flows. In addition to these natural processes, human activities affect the fragile soils as well.

Timber harvest and associated activities like road and landing construction have a number of effects on rivers, primarily by altering their watersheds. Such effects may include increased flood peaks from a basin, decreased summer base flows, increased upland ero-

sion rates, and subsequent increased delivery of fine sediment to stream channels. Such activities can also damage or destroy riparian habitat and adversely affect water quality.

In the past, timber harvests virtually devastated some watersheds and rivers, choking small drainages with debris, ruining spawning gravels and other habitats with siltation, altering natural runoff patterns, and destroying riparian vegetation. Today, state and federal enforcement of forest practices regulations can mitigate these problems. However, many rivers and streams are still in a degraded condition from past impacts and imperfect current practices.

A marked increase in the extent of clear-cut timber harvest over the past two decades, especially on National Forest lands and privately-owned parcels within them, has drawn attention to the cumulative effects of many individual timber sales within a drainage basin over a period of years. These cumulative watershed effects (CWEs) are manifest in erosion of gullies (especially below landings and logging roads), delivery of fine sediment to stream channels (with deleterious effects on aquatic life), increased flood peaks for a given storm or snow melt (resulting in erosion of channel bed and banks as the channel adjusts to the higher peak flows), and decreased summer base flows (resulting in a reduction in aquatic habitat and increased summer temperatures).

Timber harvest itself is one of the most visible (though not major) culprits in producing CWEs. Tree canopy or cover over the land plays an important role in watersheds by intercepting precipitation and slowing runoff, which results in more precipitation infiltrating into the ground (from which it can emerge slowly into the stream over the summer months) and less immediate runoff during winter storms. In addition to tree cover, a duff layer (organic mulch) on top of the soil aids in water absorption. Heavy logging eliminates these important functions. Tree roots also impart considerable strength to hill slopes and stream banks. Usually, ten years after trees are cut, their roots have rotted enough that they no longer stabilize the hill slope, and landslides may ensue. Stump sprouting of redwood and black oak are exceptions to this trunk decay.

The tracks left by equipment in the course of removing cut trees can also serve to concentrate flow, resulting in the development of gullies. This is especially true in tractor yarding, in which tractors are used to carry trees from an upper hill slope to a lower landing, because these tracks tend to converge to a point in a down slope direction. Cable yarding, in which logs are dragged up the hill slope to an uphill landing, results in tracks that radiate outward down slope, and thus tend to disperse runoff. The operation of heavy equipment across the land surface also compacts the soil, resulting in less infiltration and more runoff and erosion. This is one reason why cable and helicopter logging have fewer impacts.

The construction of logging roads and landings produces the greatest hydrologic effects, and in some forest areas contributes the

single largest source of excessive sedimentation, because all precipitation runs off bare, compacted surfaces. The roads also alter the natural drainage pattern, intercepting small drainages and diverting them to others, resulting in increased flow down fewer channels. Seemingly subtle alterations of the drainage network can result in large gullies down slope. The effect of roads is persistent, because unless roads are physically removed (which is rarely done), their hydrologic effects continue, although erosion rates from the roads themselves can be expected to decline if they are not heavily used (Reid and Dunne, 1978).

Increased erosion from logging and road building results in elevated suspended and bedload sediment loading in streams and rivers down slope and downstream of the activity, adversely affecting aquatic biota (Everest et al., 1987; Newcombe and MacDonald, 1991). This is especially true for sites with steep slopes, fine-textured erodible soils and high rainfall, or where shallow soils overlay impervious soils or substrata. A direct effect of heavy siltation is the smothering of incubating salmonid eggs or emerging alevins in spawning gravels. Long-term degradation of gravels and other habitat features also occurs until excess sediments are washed through, if ever. Silt-laden waters also reduce the abundance and diversity of other aquatic organisms.

Unless an undisturbed buffer strip of forest and riparian vegetation between the stream and the logged areas is maintained, large amounts of logging debris may end up in the waterways of a logged area. This material robs the aquatic ecosystem of its oxygen supply as the material decomposes. Such conditions are particularly damaging to aquatic life during the summer, especially under low flows and with temperatures in the upper tolerance range and when salmon, steelhead and trout eggs are developing and hatching in the gravels.

Another effect of logging on riparian habitats is increased water temperatures. Tree canopies greatly moderate the daily temperatures and reduce summer maximum temperatures on the forest floor and its streams. Water temperatures in headwater streams are a major determinant of the temperature of downstream, midsize streams and rivers. The cumulative effects of temperature increases in tributaries could cause adverse changes in the environment of downstream reaches, which are often important salmonid rearing habitats. Buffer zones, if wide enough, can significantly ameliorate potential temperature effects of logging (Beschta et al., 1987).

## Grazing

Livestock grazing by sheep and cattle occurs on half of all the undeveloped land in California, but is mainly concentrated in the Central Coast region, the San Joaquin Valley, and the foothills. The most valuable rangeland in this state is grassland, but shrub and woodlands are also used for domestic livestock. Although some pastures are irrigated, seeded or fertilized artificially, most rangeland is not actively manipulated. The primary method of range management is controlling when and where the livestock is grazed.

Cattle prefer grasses while sheep prefer broad-leaf herbaceous (nonwoody) species, but both will browse on trees and shrubs within reach if other forage is unavailable. In most parts of the state, the dominant European grasses which replaced the native bunch grasses dry up in the autumn, leaving trees and shrubs, especially the younger plants, the only green feed around. Grazing may be year-round or seasonal on any particular area, depending on the climate and vegetation of an area, as well as the market. Livestock grazing, depending upon stocking rates and timing, can have significant effects on the plant growth of the grazed area, and can even determine whether tree and shrub regeneration occurs.

Livestock grazing is increasingly recognized as a major cause of increased erosion rates and degradation of water quality (Armour et al., 1991, Chaney et al., 1990). Livestock eat tree seedlings and trample vegetation along stream banks, resulting in a decline in riparian vegetation and the loss of the vegetation's functions of bank

Figure 37. Cattle Grazing.





stabilization, shading and filtering fine sediment from runoff. Loss of vegetation also reduces food sources both through leaf litter and insects for aquatic animals. Livestock chisel banks with their hooves, breaking down the banks and introducing sediment directly to the stream. To a certain degree, livestock waste can directly impair water quality by introducing pathogens and excess nutrients into the surface water.

Completely fencing off riparian areas from livestock has been successfully used as a basic first step in encouraging natural recovery of degraded stream channels (Elmore, 1989). In some instances, grazing can be allowed in riparian areas without significant harm to stream banks and riparian trees and shrubs, but the timing and intensity of the grazing must be carefully monitored and managed.

## **Effects of Water Diversion, Flood Control and Channelization**

### ***Dams and Diversions***

The profound changes on California rivers caused by dams are exemplified by Shasta and Friant dams in splitting the Sacramento and San Joaquin river systems in half. In vernacular usage there are two "Upper Sacramento Rivers," one above Shasta Dam, and one from Keswick (Shasta) Dam to the mouth of the Feather River. Similarly there are two "Upper San Joaquin Rivers," one above Friant Dam and one from Friant Dam to Mendota Pool.

Dams in California are built and operated primarily for flood control, water supply, the production of hydroelectric power or a combination of these uses. Recreation, fish and wildlife are also sometimes additional stated purposes for dam/reservoir projects, albeit subservient to flood control, human water supply and power. Smaller dams may be built for purely recreational uses. These are often installed seasonally. The patterns of flow releases out of a dam—its operations—depend upon the project's purpose(s) and the weather.

### **The Feather River**

The Pacific Gas and Electric's (PG&E) moniker of the "Stairway of Power" belongs to the Feather River. In the 1880s civil engineers noted the region's natural advantages of underground storage of water in the porous volcanic rock formation. Beginning in 1913 ten PG&E powerhouses were built utilizing the river (PG&E, 1987).

The future governor of California, Spanish Captain Luis Arguello, exploring the river in 1817, named it El

*Continued on next page*



Rio de las Plumas (the River of the Feathers) because of the myriad "feathers" of wild fowl floating on the water (the feathers may have been willow pollen).

On the North Fork of the Feather River, a major branch of the Feather River which, in turn, is a major tributary of the Sacramento River, are two large hydroelectric facilities—Rock Creek and Cresta—which have shackled the power of the river to generate electricity. In the process they also have seriously damaged what was once one of the state's finest trout fisheries.

In the early 20th century, the North Fork of the Feather River was an outdoor paradise. Its sparkling waters, magnificent and breathtaking scenery and trout-rich pools drew fishers from around the world (*Sacramento Bee*, Oct. 11, 1991). Decades of logging, livestock grazing and road building upstream have flushed mountains of silt and sediment into the watershed. These problems, coupled with hydroelectric dams on the river which diverted river flow through tunnels and penstocks and effectively eliminated the former extreme spring floods and summer low flows, have led to low wild trout populations. In the upper reach of the river spared the development activity, it has been demonstrated that a substantial population of wild rainbow trout can maintain themselves and large populations of nongame fish when environmental conditions are favorable for trout growth and survival (Moyle et al., 1983).

A recent agreement between PG&E and the Department of Fish and Game promulgates repair of the watershed by increasing stream flows, reducing the impacts of cattle grazing in Humbug Valley, drawing cooler water out of Lake Almanor to reduce downstream water temperatures during the summer, improving fish habitat in important tributaries and providing for scientific monitoring.

The ecological damage on this river is so severe that conservationist and fisheries interests are skeptical about the future for this once prolific aquatic ecosystem.

Characteristic operations of most water supply and flood control dams include a decrease in high natural flows when runoff peaks from winter rains and/or spring snow melt are stored behind dams. Flood control reservoirs can contain larger floods than reservoirs operated solely for water supply, and the larger the

reservoir capacity relative to river flow, the greater the reduction in peak floods. Sometimes reservoirs are not able to store the most extreme flood peaks, either because of their size or because they were previously filled to capacity, and spill releases result.

Water that is stored in reservoirs is later released downstream over the dry season. In California, agriculture uses 85 percent of developed water sources; thus releases usually coincide with crop demand. Rivers which normally would be quite low in flow in summer may have their flows augmented. Their once natural channels are used as canals for water transfer to downstream users.

Some rivers have flow augmentation because of water transferred from other drainages. The Upper Owens River near Mammoth Lakes has experienced increased flow since 1941, when water was first transferred from the Mono Lake Basin via the Mono Craters Tunnel. The Sacramento River below Shasta and Keswick dams has received about 70 to 90 percent of the runoff of the Trinity River at Lewiston since 1963 through the elaborate system of dams, reservoirs and other works of the federal Central Valley Project.

### Direct Effects on Living Resources

The most obvious effects on river systems from dams are the loss of free-flowing waterways and the loss of river aquatic, riparian and upland habitats inundated by reservoirs. Dams frequently completely block passage by fish, other biota and human users. Anadro-

Figure 38. Stranded Fish.

*"A True Fish Story" Edited version of postcard text, dated 1899.*

Scene on Kelsey Creek, seven miles from Lakeport, one mile from Kelseyville. Every spring the fish run up the Creek to spawn, sometimes in such quantities that the high water subsiding quickly often leaves them stranded.



Bryant Sturgess Collection.

mous fish are particularly affected by the physical barriers of large dams. Over 95 percent of the historic salmon and steelhead spawning habitat in Central Valley river systems has been eliminated, primarily by the construction of large dams on every major river (California Advisory Committee on Salmon and Steelhead Trout, 1988).

Other direct effects of large dams on fish and other aquatic biota are inappropriate increases and decreases in flows, and changes in water temperature. Rivers can be defined partly on the basis of a more or less predictable and lengthy flood pulse, as opposed to the brief and unpredictable floods of smaller streams (National Research Council, 1992). Native aquatic biota evolved and survived under certain environmental conditions, and artificial changes to their environments usually have detrimental effects. Sudden flow decreases may dry up gravel spawning sites or strand fish in backwater pools. Sudden increases can scour away spawning beds or the algal and invertebrate communities growing on bottom surfaces. Other unnatural flow reductions can prevent fish from receiving appropriate migratory cues. Flows also affect water depth and temperatures, influencing the amount and quality of aquatic habitat, and the passage of fish over instream obstacles such as shallow riffles. Generally, the higher the flows, the cooler the instream water temperature.

#### A New Era

In 1902, Congress enacted the Reclamation Act and created a Reclamation Service to implement it. The purpose of the act was to open new lands in the West for settlement through irrigation.

The Central Valley Project Improvement Act (Public Law 102-575, Article 34 [Miller-Bradley Act]), enacted in 1992, is said by many to be the most important water reform in California in the last three decades. For the first time, natural habitat protection must be seriously considered when decisions are made about California's water resources under federal control. In addition, specific set-asides have been established for fish and wildlife protection.

This landmark legislation will likely result in enormous changes in California water policy by increasing allocations for environmental protection, reforming water contract policy and pricing, and permitting water transfers (water marketing) that will allow contract water purchasers to transfer water at a profit.

The act adds important new purposes to the Central Valley Project (CVP). They are: to protect, restore and enhance fish, wildlife and associated habi-

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tats in the Central Valley and Trinity River Basins of California; to address impacts of the CVP on fish, wildlife and associated habitats; to improve the operational flexibility of the CVP; to increase water-related benefits provided by the CVP through expanded use of voluntary water transfers and improved water conservation; to contribute to California's interim and long-term efforts to protect the San Francisco Bay and Sacramento-San Joaquin Delta Estuary; and to achieve a reasonable balance among competing demands for use of CVP water, including requirements of fish and wildlife, agriculture, municipal and industrial, and power contractors.

The act makes "mitigation, protection, and restoration of fish and wildlife" new purposes of the CVP, presumably on equal footing with preexisting project purposes such as water supply, flood control and power.

Within three years the Secretary of Interior must develop "a program which makes all reasonable efforts to insure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long term basis, at levels not less than twice the average levels attained during the period of 1967-1991." There are also provisions that authorize and direct the secretary to "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing fish, wildlife and habitat restoration purposes and measures."

The act establishes a restoration fund created to provide up to \$50 million annually for the restoration of fish, wildlife and habitat. The money for this fund comes from the new payments imposed on CVP water contractors and transferees of CVP water. (These payments are to be at the maximum rate of \$6 per acre-foot for agricultural water, \$12 per acre-foot for municipal and industrial water, and \$25 per acre-foot for any water sold or transferred to an entity which has not previously been a CVP customer. It is argued that this additional fee may make CVP water too expensive for non-CVP agricultural users to purchase in a transfer).

The secretary must develop plans within three years for "improvements in, modifications of, or additions to the facilities and operation of the project, con-

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servation, transfers, conjunctive use, purchase of water, purchase and idling of agricultural land and direct purchase of water rights" in developing the additional yield. A new era in water management has begun with the above agenda to guide the direction of water reform.

The most dramatic example of the impacts of dams on salmon is Friant Dam on the San Joaquin River. The dam's construction resulted in the extinction of the largest spring-run chinook population in the state. The dam blocked upstream spawning grounds. Downstream of the dam, San Joaquin River flows in spring, summer and fall are minimal, and the riverbed completely dries up every year in the reach upstream of the Mendota Pool in Fresno County.

Larger reservoirs develop stratified water temperatures, with warm water on the surface and cool water at lower depths. Reservoir releases which come from the surface can raise temperatures adversely downstream. On the other hand, if dam releases tap from the cold pool, water temperatures below the dam can be significantly lowered.

Due to this cold pool effect, Shasta Dam for a time mitigated partially for some of its detrimental effects on salmon: The dam closed off access by salmon to historic cool water in the McCloud, Pit and Upper Sacramento rivers, but cold water releases increased spawning below the dam over what it was naturally. Winter-run chinook numbers in particular rose dramatically from cold water releases (Fry, 1979). However, during drought times, the cold pool in the reservoir decreases with decreasing water level. Under the recent drought (1987-1993), the Bureau of Reclamation had to operate Shasta Dam by choosing between cold water releases for fish, power production through turbines which tap into warmer reservoir layers, and storing and delivering water supplies for customers of the Central Valley Project. Recent declines of salmon runs and the size of the cold pool necessary to support them have been so severe that in September of 1992, nine fishing and conservation groups filed suit to force the Bureau to give the disappearing salmon stocks first priority over other uses. The suit was dropped in December, 1992, at least for the time being.

Smaller dams are not without problems. Red Bluff Diversion Dam on the Sacramento River, Daguerre Point Dam on the Yuba River, Woodbridge Diversion Dam on the Mokelumne River, and Benbow Dam on the South Fork Eel River are examples of smaller size dams which have affected anadromous fish. Poorly designed fish ladders, inadequate releases for upstream attraction flows or out-migration flows can delay or block salmon and steelhead runs and block American shad and striped bass runs.



Seasonal recreation dams can also be very damaging to salmon and trout. Out-migration of juveniles may be totally blocked, water releases are usually minimal, and temperature of the impounded water increases, thereby reducing the habitat values of both the impounded and released water.

Single-purpose hydroelectric dams affect aquatic and riparian habitats and biota by upstream inundation, large and rapid flow alterations, and sometimes the complete dewatering of downstream reaches if the flow is diverted through long penstocks.

Water diversions can affect aquatic life when organisms are sucked directly into intake pipes. Some diversions have screens which are meant to prevent fish from being entrained, but these are often ineffective, especially for eggs, larvae and juveniles of salmonids and other anadromous fishes. Most individual diversions are unscreened, numbering in the hundreds in Central Valley rivers. Up to 10 million juvenile salmonids are estimated to be lost to unscreened diversions on the Sacramento River alone (Upper Sacramento River Fisheries and Riparian Habitat Advisory Council, 1989).

### Effects On Stream Processes

Some of the most significant impacts dams and diversions have on the character and functioning of rivers in California are through changes of geomorphic processes. To understand the nature of these changes, it is helpful to view them in terms of the independent variables that control alluvial channel geometry: flow regime and sediment load. Changes in these variables will produce adjustments in alluvial channels—the nature of which will depend upon the precise nature of the flow regime and sediment load, and how they are changed. Some general trends are outlined below.

Dams disrupt the longitudinal continuity of the river system, interrupting the action of the “conveyor belt” of sediment transport. Upstream of the dam, all bedload sediment and most suspended load is deposited in the quiet water of the reservoir, while downstream, water released from the dam possesses the energy to move sediment, but has no sediment load. Clear water released from the dam is known as hungry water, because the excess energy is typically expended on erosion of the channel bed and banks for some years following dam closure. For example, on Stony Creek (a tributary to the Sacramento River), since the closure of Black Butte Dam in 1963, the channel downstream has undercut and migrated laterally, annually eroding enough bedload sediment to compensate for about 20 percent of the bedload now trapped annually by the dam (Kondolf and Swanson, 1993).

Channel erosion below dams is frequently accompanied by a change in particle size on the bed, as gravels are transported downstream, leaving a coarse lag deposit of cobbles, known as an armor

layer. Development of the cobble-bed is an adjustment by the river to changed conditions because the larger particles are less easily entrained by the hungry water flows below the dam. However, this change in particle size can be detrimental to salmon populations, which require gravel for spawning. This problem has been observed on many rivers in the state, including the American River below Folsom and Nimbus dams, the Sacramento River below Shasta and Keswick dams, the Mokelumne River below Camanche Dam, and the Carmel River below Los Padres and San Clemente. In these (and other) cases, gravels suitable for spawning have been artificially placed in the channel in an attempt to restore the lost spawning habitat.

Downstream of a reservoir, the river may respond to the reduction in flood scour by narrowing its channel with encroachment of riparian vegetation into parts of the active channel from which vegetation formerly was scoured annually, and by depositing sediment along channel margins. Vegetative encroachment synergistically feeds the process of armoring and channelization by increasing sediment stability (Williams and Wolman, 1984). Once thick vegetation becomes established, flows which previously might have scoured the channel no longer are as effective.

If dams impede natural geomorphic processes to a significant degree, riparian vegetation regeneration over the flood plain will be affected. On the Colorado River, dams almost completely prevent overbank flooding and meander, and have so severely depleted base flows that the regeneration of native riparian vegetation has been essentially eliminated (Ohmart et al., 1977).

Vegetative encroachment has been observed below a number of dams in California—such as on the lower Stanislaus, Tuolumne and Merced rivers (Pelzman, 1973). Pelzman suggested that vegetative encroachment may be exacerbated by summertime flow augmentation. He observed that there was little extra plant growth below a dam on the Yuba River, which at that time had releases which were similar to the pre-project flow regime, i.e., a more natural decline in summer flows.

Channel narrowing has been greatest below reservoirs that are large enough to swallow the river's largest floods, such as on the Trinity River (Figure 80, Chapter 4) and Anderson Reservoir on Coyote Creek. Coyote Creek, which flows through the urbanized San Jose area, was dammed for water supply in 1936 and 1950. Its channel has since narrowed to less than 50 percent of its pre-dam width, and a riparian forest has encroached upon the surface of the formerly active channel (Kondolf and Matthews, 1990).

In some cases, fine sediment delivered to the river channel by tributaries accumulates in spawning gravels because there are no more natural floods to flush the river bed clean. The Trinity River below Trinity Dam is probably the best known example of this in California, with accumulation of sand in the riverbed and consequent

destruction of the invertebrate community and salmonid spawning habitat (Fredericksen and Kamine, 1980). Experimental, controlled releases are now being conducted to determine the flows required to flush the sand from the gravels in the Trinity River (Kondolf and Wilcock, 1993).

Flows, primarily during the drier seasons, can also be affected by direct diversions from a stream or river or by groundwater pumping from interdependent aquifers in the flood plain. Extensive groundwater pumping in the flood plain of the Carmel River in the 1960s and early 1970s resulted in the death of large amounts of riparian vegetation. This in turn contributed to channel instability so that relatively low magnitude storm floods in 1978 and 1980 resulted in huge amounts of erosion and channel widening (Kondolf and Curry, 1986).

### The Owens Valley Perspective

The export of water from Owens Valley to Los Angeles has had dramatic effects on the environment, economy and way of life of this valley. Owens Valley is approximately 100 miles long and varies in width from 6 to 15 miles. It is situated between the Sierra Nevada and the Inyo/White mountains approximately 250 miles north of the City of Los Angeles. The high mountain peaks (10,000 to more than 14,000 feet) block precipitation, creating a rain shadow in the valley. Although the valley receives an average annual precipitation of only four to six inches, runoff from the Sierra Nevada snowpack in streams that flow through the valley into the Owens River creates riparian and wetland environments.

Historically, the Owens River, originating in Long Valley in Mono County and terminating at Owens Dry Lake, supported riparian habitat and fisheries and provided recharge to the Owens Valley groundwater basins. Meadows, springs and marshes in the valley supported wetland plant and animal species (See Chapter 3).

Surveys made in 1885 showed that it would be feasible to construct a gravity flow aqueduct from the Owens River to Los Angeles and began a history of land deals, betrayal, wasted land, violence and litigation (Reisner, 1986). Los Angeles' diversion activities over the last 80 years from over 50 miles of the Owens River and portions of its tributary streams

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caused the destruction of the associated riparian vegetation, fisheries and wildlife habitats. These diversions also led to the drying up of the 100-square-mile Owens Lake. Groundwater pumping has dried up an extensive spring and marsh system, destroyed associated vegetation and wildlife habitats, caused the reduction of diversity and density of groundwater-dependent vegetation over large areas, and lowered water levels in privately owned domestic and irrigation wells.

When a Memorandum of Understanding was adopted by Inyo County and Los Angeles in 1982, the first step was taken to cooperatively study the relationship between groundwater pumping and its impact on native vegetation. Efforts for a long-term management plan include a management goal of avoiding changes and decreases in areas of riparian vegetation dependent on springs and flowing wells, stands of willow trees and cottonwoods, and in rare or endangered species.

The management agreement also provides for the implementation or construction of certain projects. These projects include rewatering 53 miles of the dry channel of the Lower Owens River, including the establishment of off-stream ponds and wetlands; releases of Los Angeles-owned lands for public and private use; permanent transfers of the Owens Valley water systems from Los Angeles to local entities; control of an invasive plant called salt cedar; and other environmentally oriented projects. In addition to some question about the ethics of this agreement, there have been legal challenges.

When one views the Owens Valley in the context of urban growth in other areas of California, it becomes apparent that despite environmental problems caused by water export from the Owens River by the Los Angeles Department of Water and Power, the Owens Valley remains one of the most choice and beautiful areas in the state. This is a direct result of land management and ownership policies of the City of Los Angeles which have discouraged extensive urban development and, by so doing, have spared the Owens Valley the myriad problems plaguing developed (and developing) urban areas. The long-term economic future of the Owens Valley lies in its enormous and unmatched recreation potential. The value of the east slope recreation resource is only

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beginning to be realized. Already the Inyo National Forest alone supports more recreation use than Yellowstone, Grand Canyon and Glacier national parks combined—more than 7 million visitor days in 1983—and use increases annually. Urban development would ruin this special area. One 40-year resident of Bishop summed up this concept as follows: “In the long run, the one thing that would be far more damaging to the Owens Valley than having the City of Los Angeles here would be NOT having them here!” (Phil Pister, pers. comm., 1993).

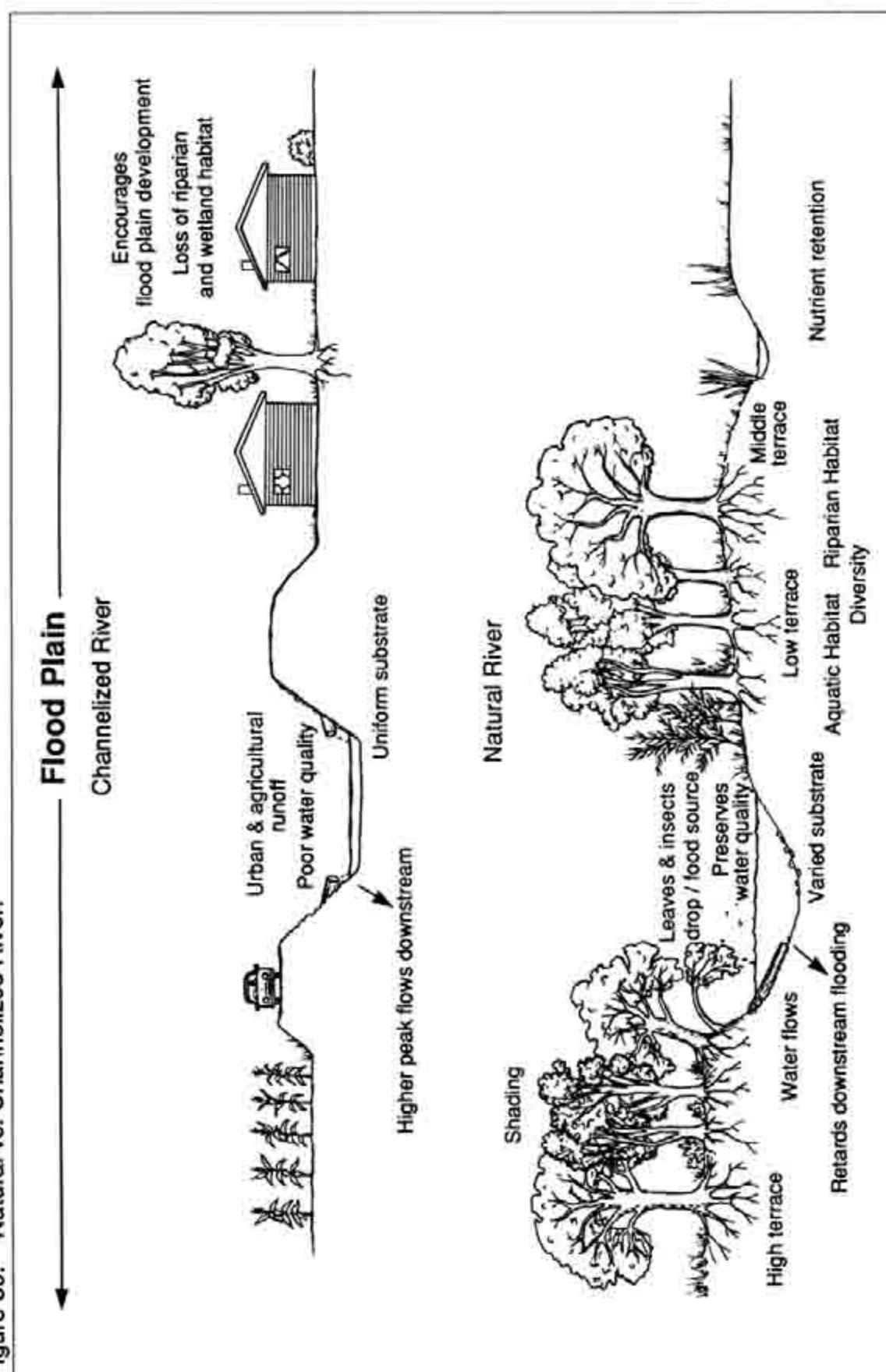
### Effects of Flood Control and Channelization

Complete channelization converts an irregular, typically meandering, natural channel into a straight, geometrically simple canal. More often the case in large rivers, meander bends are maintained, but the banks are engineered to a given slope (e.g. 2:1), and armored with rock revetment, also called riprap. Such bank protection attempts to stabilize the active channel and prevent bank erosion. Other purposes of channelization include increasing the efficiency with which water can be conveyed through the channel for flood control or irrigation, draining lands bordering the channel, and improving navigation. Channelized reaches typically have an active channel wider and deeper than the natural channel, with smooth banks devoid of vegetation or irregularities (at least upon construction). Where channelized reaches are not protected by concrete beds and banks, the artificial channel dimensions are frequently unstable, and the channel undergoes adjustments both within the modified reach and in adjacent reaches (Brookes, 1988).

Channelization produces a suite of negative ecological effects, mostly related to the loss of habitat diversity created by bends, pool/riffle sequences, sunken woody debris and other irregularities (Figure 39). The rectangular or trapezoidal engineered channel lacks the cover, food sources, instream nutrient detention and protection from high velocities afforded by the natural channel. Often fish migration is hindered by uniformly high velocities across the channel. Commonly the channelized reach is devoid of bank vegetation to reduce hydraulic roughness (resistance to flow) and for easier maintenance. As a result, riparian habitat is lost, and the shading and food production provided by overhanging vegetation is lost to the aquatic community. Perhaps the most adverse effect of channel stabilization is its impact on riparian plant community succession. One of the most important river processes determining riparian succession is the erosion and deposition which naturally occur as the river migrates over its flood plain. Anything which interferes with the



Figure 39. Natural vs. Channelized River.



Adapted from Stream Renovation Committee Guidelines, 1983.

establishment of new sand and gravel bars, and overbank depositions of sediment, will also interfere with the establishment and subsequent development of the various plant communities that make up riparian habitat.

Under various Army Corps of Engineers flood control projects, the Sacramento River has been subjected to enormous changes by the levee system and by efforts aimed at stabilizing the river channel using rock or other types of bank protection. These include the Chico Landing to Red Bluff Project, the Sacramento River Flood Control Project and the Sacramento River Bank Protection Project. Such programs have reduced or eliminated the ability of the riparian vegetation to regenerate itself and eliminated shaded riverine aquatic habitat. Bank stabilization is the primary threat to the survival and recovery of the Bank Swallow, a state-listed Threatened species, which nests in eroding banks.

The use of straightened, often concrete-lined, channels to achieve flood control has been the mainstay of what has been referred to as "single-objective flood control": to convey floodwater as efficiently as possible and to leave as much land as possible for development. This approach left little room for aquatic or riparian habitats and their needs. Some spectacular recent failures—such as the San Lorenzo River in the City of Santa Cruz (Williams and Swanson, 1989) and cases where channelization has caused dramatic channel instability (Simons and Hupp 1986)—cast doubt on the effectiveness of traditional channelization projects in achieving their single objective.

Conventional engineering approaches have relied on hydraulic design criteria developed in artificial, controlled situations, but these methods have resulted in a number of problems. Commonly, designers of flood control projects have underestimated a number of critical factors, including channel roughness (resistance to flow), effects of sediment and debris, and channel bed erosion and deposition during floods. In addition, requirements for expensive channel maintenance, such as clearing sediment or vegetation, are not realistically considered. Channels are designed to carry a certain amount of water at a certain velocity under the assumption the channel bed and walls are smooth, or have low roughness. However, floods often convey large amounts of bedload sediment into the design channels, increasing roughness so much that water does not flow as planned and can even overtop channel banks. Similar effects occur when flood-carried debris blocks flows, causing water to back up and flood out of the channel. In channels with unlined bottoms, scour and/or deposition can occur, and sometimes straightened channels attempt to reestablish natural meanders. Such changes in channel morphology also lead to project failures (Williams and Swanson, 1989).

An accurate evaluation of the true costs and benefits of conventional designs would likely cast a more favorable light on multipurpose

stream and river management schemes which incorporate environmental values such as natural flood plains and aquatic habitats, but which heretofore had been considered too expensive.

## **Effects of Agriculture**

California is the national leader in agricultural production, has been for more than 40 years. The state's \$18.5 billion a year agricultural industry (Department of Food and Agriculture, 1992) is noted not only for its high value, but for its great diversity of products. California leads in over 60 different crop and livestock commodities, which fall under all major categories: livestock, fruits, nuts, vegetables, field crops (including cotton), nursery products and flowers. Farming and ranching occupy 30.6 percent of the state's land (Bailey, 1993).

Crops and the cultural practices used to grow and harvest them vary greatly. Some crops are annual, and live only one growing season, while others are perennial, such as vines, shrubs and trees. Annual crops are generally harvested and tilled under by the end of the summer growing season and not replanted until spring. This leaves the ground bare or nearly bare during the rainy season. Perennial crops stay rooted, but the ground under or around the plants is also usually tilled for fruit harvest and weed control.

Agricultural crops are a monoculture of species developed primarily for commodity production, rather than any kind of hardiness, and are thus vulnerable to attack by disease, insects and other pests. Common agricultural practices in California apply pesticides to combat plant disease and pests, although "organic" farming is growing in popularity.

Most crops in the state require irrigation during California's rainless growing season. Over 8.5 million irrigated acres use 85 percent of the state's developed water. This water is captured and delivered by systems of dams, aqueducts and canals. In addition, in many parts of the state, agriculture relies on groundwater pumping for water, either used alone or in conjunction with developed surface water (American Farmland Trust, 1986).

## **Harvest of Agriculture**

California farms and ranches contribute more than food and fiber. Practices associated with farming not only increase the introduction of pollutants into streams, but also alter the physical structure and function of river-riparian ecosystems. Over 163 million pounds of pesticides and herbicides were used in 1990 by California growers (SWRCB, 1990). This is nearly one-third of all pesticide application in the entire United States. Also, agriculture changes the landscape from natural vegetation to croplands. The reduction of this natural vegetation results in more pollutants being released to the rivers.

Figure 40. Agricultural Drainage.



U.S. Soil Conservation Service.

Pollutants include sediment, animal waste, nutrients and pesticides. The SWRCB identified agriculture as contributing to over 58 percent of the pollution statewide to California's rivers (SWRCB, 1991) (Figure 29).

Examples of physical and chemical changes induced by large-scale agricultural practices are found in the rice-growing areas of the Sacramento Valley where agricultural drain water is one-third of the Sacramento River flow during peak rice irrigation in early summer. Two events in the cultivation of rice had catastrophic effects. First, short stature rice was developed at University of California at Davis for use in California rice fields in the

early 1980s. The shorter height of the rice yielded ideal growing conditions for weeds. The rice growers turned to herbicides to control the weeds. Over a three-year period, herbicides from the rice fields killed fish. The striped bass population decline accelerated, apparently because the fish were spawning at the time that the herbicides were being released on the rice fields. The histology of larval striped bass showed seriously deformed livers (Bailey, 1993). State and regional water quality people and local growers sought a solution. The solution adopted by the growers was to hold water longer in the fields and allow the herbicide to chemically breakdown, thus reducing by 95 percent the herbicide pollution in the Sacramento River from these rice fields. The second catastrophic event in the 1980s was a 30,000 carp kill which was traced to the herbicide molinate to which the carp are exceptionally vulnerable.

A number of toxic substances (herbicides and pesticides) are absorbed on soil particles moved into the stream from soil leaching. Metals known to accumulate in sediment include copper, zinc and lead.

Pesticides are also assimilated by living resources in the river. Improvement in newer pesticides provides for greater and more rapid degradation; however, degradation products can be harmful. These products and other factors such as agricultural land with persistent pesticides can cause fish kills (USEPA, 1979).

## Effects of Urbanization

### *General Effects*

When watersheds are urbanized, problems may result simply because structures are placed in the path of natural processes, or because the urbanization itself has induced changes in the hydrologic regime, which in turn impact structures.

The simplest case involves settlement on a flood plain or on an alluvial fan downstream from an undisturbed watershed. The flood plain settlements are vulnerable to large floods that may occur once every 50 to 100 years. The interval between floods is too long for the average home buyer to recognize or believe the danger, unless the event has just occurred. Even then, the home buyer may treat it as a random "Act of God" or a piece of bad luck, rather than a recurring natural event, predictable in its frequency over the long term. The distribution of large floods over time reflects the precipitation and runoff region of the watershed, and large floods are natural and necessary for the drainage of the watershed and maintenance of the river channel. Urbanization of the upstream watershed itself produces fundamental changes in watershed hydrology.

Infiltration is reduced by the creation of extensive roof area and pavement, and runoff moves more quickly from uplands to streams through storm sewers. As a result, runoff from the watershed is flashier, with increased flood hazard (Leopold, 1968). Flood control and land drainage schemes may increase the flood risk downstream by concentrating runoff. Urbanization can also produce large changes in erosion and the delivery of sediment to the stream channel. As outlined by Wolman (1967), high sediment yields of the construction phase are followed by reduced yields once the area is fully built and sewered. Water quality can actually be improved by the conversion of agricultural land to urban use (Charbonneau and Kondolf, 1991).

Figure 41. City of Sacramento During Flood of 1862.



Sacramento Archives and Museum Collection Center.

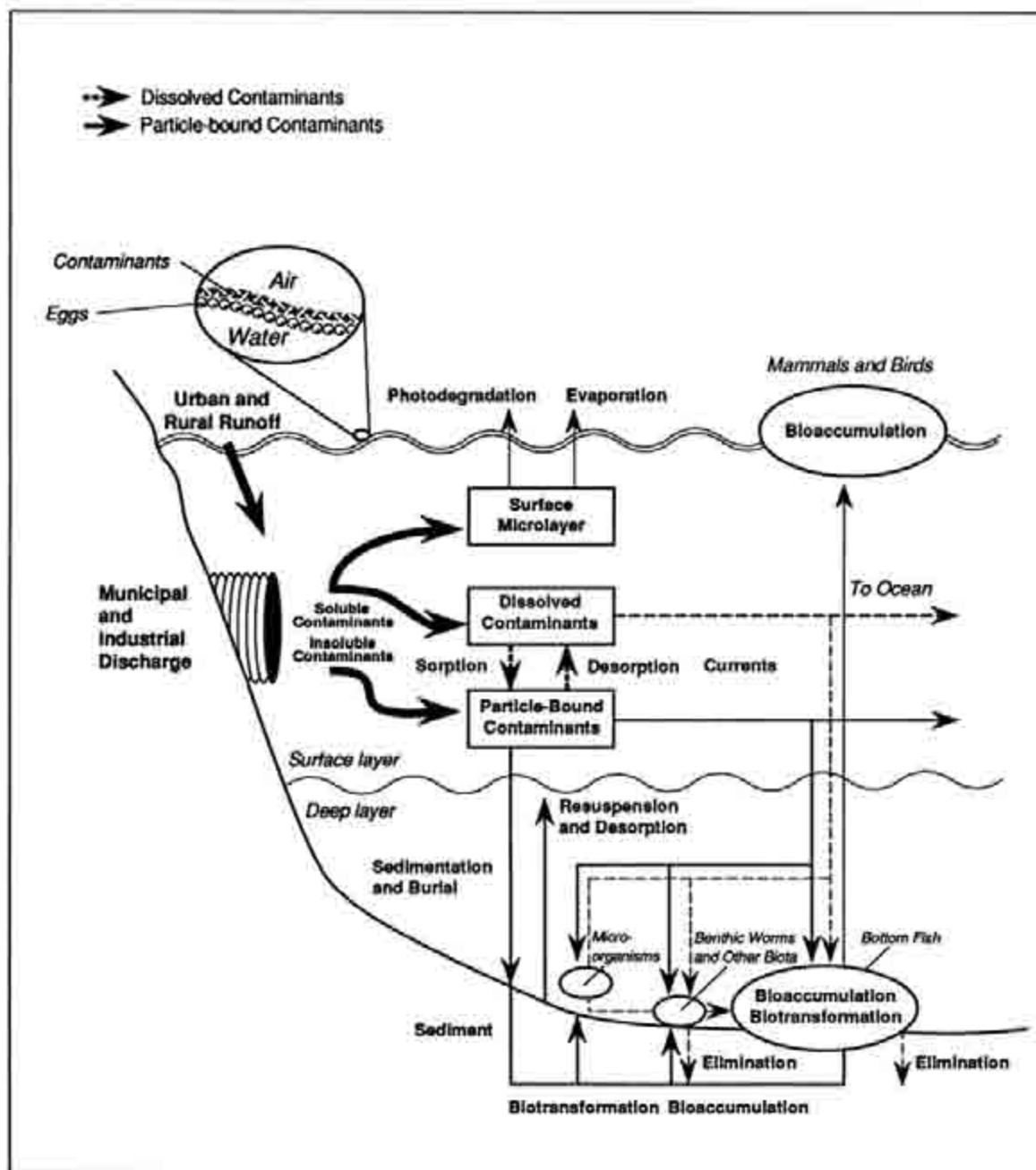


The dimensions and geometry of stream channels reflect the runoff and sediment load they carry (Leopold et al., 1964); urbanization-related changes in these variables typically induce channel widening and downcutting.

### Urban Runoff

At almost every point that urban activity touches the watershed, nonpoint source pollution (NPS) is created. Sediments washed

Figure 42. Diagram of Transport and Fate of Pollutants in Water.



Source: *State of the Estuary*, 1992. U.S. E.P.A. and the Association of Bay Area Governments

from the urban landscape and deposited in river waters include trace metals such as cadmium, copper, lead and zinc. The SWRCB identified PAHs from vehicular gasoline and oil that leaks onto roads and parking lots as a significant source of pollutants (SWRCB, 1991a). These, together with pesticides, herbicides and fertilizers, contaminate drainage waters. Urban activity also yields sediments transported to rivers which cause turbidity, concentrate toxic pollutants and destroy fisheries. (Figure 42).

Urban, agricultural and wildland runoff contribute much more significantly to river pollution than point sources such as municipal and industrial discharges. Using the Bay-Delta Estuary as an indicator, the California watershed at the urban interface appears to be under considerable stress from pollution loads. The Water Quality Assessment Summary Report published by the SWRCB in 1991, indicates that NPS pollution is the cause of 50 to 80 percent of impairment to water bodies. Earlier reports by SWRCB indicated similar finding regarding NPS.

### Dunsmuir Spill

*I think what we all want is the river to come back like it was with a healthy native trout fishery.* Leonard Everson, Dunsmuir Cafe Owner, *S.F. Chronicle*, Wednesday, June 10, 1992.

Railroad workers founded the town of Dunsmuir in 1884. It is halfway between Portland, Oregon and Sacramento on the Southern Pacific Shasta route through the Siskiyou Mountains. In the past 20 years, tourism has been the main business, replacing the dominance of the railroad.

Anglers, from California and around the nation, have contributed to the town's prosperity.

A train "mishap" in July of 1991 spilled a tanker carload of the potent soil fumigant metam sodium into the river, killing every fish along the 42-mile stretch from Cantara Loop to Shasta Lake. Also killed outright were amphibians, aquatic insects and the primary foundation of the food chain—algae and moss. The magnitude of this spill can be compared to the Mill Creek acid spill disaster, the 150-mile Tennessee Roanoke River ethyl benzene spill and acute pH stresses on the Clinch River (all in the 1970s).

The town's economic health is inextricably

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linked to the ecological health of the river. Since the catastrophe, Dunsmuir and other communities along the Upper Sacramento have suffered a substantial loss in tourism, particularly due to a ban on fishing in the river that could last until 1994. To date, the scientists, government and non-government people working on the remediation and restoration seem to have replaced the tourists. Nearly half of the \$12 million paid out by the railroad company has gone to affected businesses and residents.

Loss of wildlife is expected to be in the tens of millions. Estimations of the recovery time from the spill ranges from two to greater than ten years, depending on many factors. Favorable factors include high water levels for good dilution and the breeding season so that young fish are available for repopulation. Relatively long recovery times are believed to be due to the persistence of petroleum products (Yount & Niemi, 1990). The railroad payments have not addressed the damage caused by the spill in a comprehensive manner. Meanwhile, the state is directing the river's recovery under the Department of Fish and Game. The overall strategy is to allow "wild fish" to repopulate the river before introducing hatchery fish. Not only was the river's ecology poisoned, but some claim that the very existence of this riverside town has been threatened. People in Dunsmuir know and understand sustainable resources, both economic and environmental.

## Effects of Recreation

Because there are so many different recreational uses and users on our rivers, conflicts are inevitable. The person who wishes to anchor over a favorite fishing spot and the high speed water skier do not coexist well. The family out for a quiet picnic on the banks of a secluded river will be frustrated and possibly angered by jet skiers speeding up and down the river. The scuba divers with the gold suction dredge will muddy the waters for the swimmers downstream. Each group wants the river for a specific purpose, and resents others using the river in a way that diminishes their own enjoyment.

Basic recreation data—describing the number of users, activity participation, seasons of use and residential location of users (local, state or country)—are needed to assess the importance of the recreation resource and the effects of recreational activities on rivers. A river assessment describing stream conditions is needed: Issues of

controlled public access, resource management and stream restoration need to be addressed. Several benefits would be realized from a such an assessment, including the gathering of data on use and the conditions of streams. This information is essential to the development of a river access guide describing the facilities and opportunities available. Public awareness must be heightened regarding the legal access to streams, a recreational ethic to balance the use of streams with other resource needs, ranching needs and possible harm to ongoing ranching activities if hikers leave gates open or allow dogs to run "free", public health hazards and other law enforcement issues. And finally, a river assessment should estimate monetary values to stream resource recreation uses, particularly the benefits to the local economy.

### *Impacts of Development on Recreational Opportunities*

As discussed previously, the development of dams for water diversion and flood control has altered many river systems so that some uses have been eliminated while others are reminders of what once was. Until recently, the most successful arguments made by the Bureau of Reclamation and the Corps of Engineers during the dam building era were that rivers that actually reached the sea "wasted" water, and that lakes provided better recreational experiences than did running water. Again and again in the documents that supported yet another dam, the economic value of the existing river was shown as nonexistent, while the value of the fishing and boating to take place in the new lake was shown as very high. In the same way, the proponents of the river alteration schemes downplayed or even ignored the high recreational values of riparian habitats for recreation.

Figure 43. Riprapped River Bank.



### The Naked River—Levees Without Trees

Glen Martin, a *San Francisco Chronicle* reporter, kayaked the Sacramento River from its headwaters to San Francisco Bay in July 1992 and told his story in a week-long series, "River: A Reporter's Journey." This remarkable journey chronicled the nature and character of the largest of California's rivers, some 375 miles long, fed by the major tributaries of the McCloud, Pit, Feather, Yuba, Bear and American rivers. Martin wrote of the striking differences between the upstream river—natural and meandering, and the "strait-jacketed" engineered, downstream reaches.

Drifting past thick stands of woodland and the mouths of creeks and slough, I contemplate the wild creatures that surround me in abundance. For the most part, they remain unseen, but their presence is palpable.

I regret leaving this lovely place, with its bankside jungles and silences pierced only by bird song. Twenty miles south, "the Ditch" awaits me. It is a bleak stretch of river from Colusa to the delta, its banks largely ripped and stripped of vegetation (Martin, 1992).

Over 150 miles of the river's banks are lined with riprap, an armor layer of rocks placed on river banks or levees to control erosion (Figure 43). Prior to placing the rock, a slope is typically stripped bare of any vegetation and graded smooth. Nowadays, jagged quarry rock is the usual choice for riprap, although concrete rubble and smooth river cobbles have been used. The end result is a barren rock wall, extending from the top of the bank down under the water, nearly devoid of wildlife, aquatic or fishery habitat value.

Historically, riprapping has been done to maintain a navigational channel, keep the Sacramento from meandering and prevent flooding. By far most of the riprap on the Sacramento River has been placed by the U.S. Army Corps of Engineers and the State Reclamation Board, as part of the Sacramento River Flood Control Project. The flood control system, which mainly

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controls the lower 200 miles of river, was begun in 1914 and was essentially in place by the 1940s. The design of the flood control system for the Sacramento River depends upon a system of levees to keep flood waters off developed land, in combination with artificial bypass channels to receive redirected flood flows.

Since the 1960s, riprap bank protection in this area has been a primary component of the state and federal flood control program. Seventy percent of the banks on the river below Sacramento, and almost 30 percent of the river from Sacramento upstream to Red Bluff, is rocked.

The guiding idea behind flood control programs has been to straighten channels to provide fast drainage. The effect has been a constrained river with great energy capable of severe stream bank erosion. The engineering dilemma is to cope with the increased velocity in the artificial river channel. The Corps depends on riprap as the least costly solution. To compound the effects of the riprap, current Corps mandates require levee riprap to be clear of trees and shrubs.

As Glen Martin discovered, people responsible for flood control have always believed that trees weaken levees. However, environmental concerns over habitat loss for endangered species is directing the Corps and Reclamation Board (and its staff from the Department of Water Resources) to evaluate other approaches. For example, in other countries such as Germany, where flood control expertise is world renowned, trees are part of the levee landscape. The trees stabilize the levees by sending roots directly down to the water table rather than throughout the levee substructure.

Because the levees will be around for the foreseeable future, it seems that revegetation of the rocked banks would be the best way to compensate for the loss of wildlife habitat. I had seen some examples of this on riprapped banks west of Chico, where the Department of Water Resources has established some experiments.

It looked good. While levee revegetation does nothing to restore gravel for spawning salmon, trees planted in the riprap can ultimately consti-

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tute a new riparian forest, providing shade and food for a variety of wild animals (Martin, 1992).

### *Marinas: A Question of Carrying Capacity*

Marinas on rivers in California are varied as to the kinds of vessels they accommodate. From a residential or clubhouse pier with tie-ups to facilities with more than a 100 covered berths and transient tie-ups, these facilities are relatively permanent structures within rivers. They account for a large portion of the boating traffic on the waterways. In this context, marinas include private nonprofit (yacht clubs) and commercial berthing, docks and launch facilities. The majority of marinas on California's rivers are concentrated in the Sacramento/San Joaquin River Delta. Other river marinas are located on the Klamath in the north and on the Colorado River in the south. Figure 45 shows the approximate number of marinas and yacht clubs in the Delta. As in many instances when looking for information on California's rivers, there is no one source of information regarding the number of and statistics on all marinas within the state. Not all marinas on California's rivers require leases from the SLC; all new facilities are reviewed for public trust consistency.

Marina development creates several problems: Too many marinas within a river reach generates a "tunnel effect," where marinas reach out from both banks of the river. These marina rows are visually unattractive and often are a visual barrier on the river. Residential piers, although individually less intensively used than

Figure 44. Marina on the San Joaquin River.

